1993

Illinois Agricultural Pest Control Handbook

University of Illinois
at Urbana-Champaign
College of Agriculture
Cooperative Extension Service
in Cooperation with
the Illinois Natural
History Survey

Illinois
Agricultural
Pesticides
Conference

The information in this handbook was prepared by specialists employed by the University of Illinois at Urbana-Champaign, College of Agriculture, the Cooperative Extension Service, the Illinois Natural History Survey, and the U.S. Fish and Wildlife Service. The suggestions herein are intended to provide guidelines for pest management in Illinois during the current calendar year only.

Because of changing laws and regulations, the Illinois Cooperative Extension Service assumes no liability for the recommendations for using pesticides that are included in this handbook. These recommendations are incomplete; therefore, they should be used only as guidelines. Complete instructions for the use of a specific pesticide are on the pesticide label. Read and follow the label directions and precautions before applying any pesticides. The pesticide user is responsible for applying pesticides according to label directions, as well as for problems that may arise through misapplication or misuse of the pesticide.

Not all pesticides registered for crop pests are included in this handbook. Effective pesticides that do not present an undue hazard to the user and the environment are suggested whenever possible. Trade names have been used for clarity, but their use does not constitute an endorsement by the University of Illinois, nor does it imply discrimination against other products.

Label changes, product cancellations, and changes in recommendations may have occurred since the publication of this handbook. Check with your nearest Extension office if you are in doubt about a pesticide that you plan to use. Announcement of new registrations, label changes, and changes in recommendations will be made through newsletters and appropriate media sources.

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Kevin L. Steffey

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Acknowledgments

The compilation and publication of this handbook require considerable coordination and cooperation among several units in the College of Agriculture at the University of Illinois. Without the dedication of the individuals involved in this effort, the Handbook could never be published as a whole. Following is a list of the people responsible for the production of the *1993 Illinois Agricultural Pest Control Handbook.*

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Contents

Subject Index vii

Field Crops and Livestock

1. Insect Pest Management for Field and Forage Crops 3
2. Alternatives in Insect Management: Field and Forage Crops 41
3. Weed Control for Corn, Soybeans, and Sorghum 67
4. Weed Control for Small Grains, Pastures, and Forages 97
5. Controlling Johnsongrass, Shattercane, and Sorghum-Almum in Illinois 111
6. Plant Disease Management for Field Crops 119
7. Controlling Rodent Damage in Conservation Tillage Systems 139
8. Insect Pest Management for Stored Grain 143
9. Insect Pest Management for Livestock and Livestock Buildings 155

Vegetable Crops

10. Insect Pest Management for Commercial Vegetable Crops 181
11. Weed Control for Commercial Vegetable Crops 201
12. Plant Disease Management for Commercial Vegetable Crops 223

Noncrop Weed Control

13. Brush Control in Illinois 241
14. Weed Control for Noncrop Areas 251
15. Controlling Aquatic Vegetation 257

Pesticide Information

16. Application Equipment and Calibration References 265
17. Insecticide Formulations and Toxicities 301

18. The Toxicity of Herbicides 311

19. Herbicide Formulations and Toxicities 315

20. Environmental Toxicities and Properties of Common Herbicides 331

21. Factors Affecting Herbicide Persistence 337

22. Testing for Herbicide Residues 341

23. Suggestions for Minimizing Bee, Fish, and Wildlife Losses from Pesticides 345

24. Restricted-Use Pesticides 351

Appendices

Appendix A. Poison Information Resource Centers 359

Appendix B. Pesticide Labels and Safety 361

Appendix C. Special Registrations 363

Appendix D. Groundwater Protection 365

Appendix E. Endangered Species Act 367

Appendix F. Where to Get Additional Information 369

Subject Index

Endangered Species Act . . . 367

Groundwater Protection . . . 365

Information Sources . . . 369

Insect Management

Alternatives to synthetic chemical insecticides:

- field and forage crops . . . 41
- microbial insecticides . . . 23

Insect pest management for:

- field and forage crops . . . 3, 41
- livestock and livestock buildings . . . 155
- stored grain . . . 143
- vegetable crops, commercial . . . 181

Pesticide Application Equipment

Calibration . . . 265
Equipment . . . 265

Pesticides

Environmental hazards

- bee toxicity . . . 301, 345
- bird toxicity . . . 301, 331, 345
- fish toxicity . . . 301, 331, 345

Herbicides

- formulations . . . 315
- half-life persistence . . . 331, 337
- residues . . . 341
- toxicities . . . 311, 315

Insecticides

formulations 301
toxicities 301

Poisoning 359

Restricted use 351

Safety 361

Special registrations 363

Plant Disease Management

Plant disease management for:

field and forage crops 119
vegetable crops, commercial 223

Rodent Control in Conservation Tillage Systems 139

Weed Control

Control in (site):

corn 67
forages 97
noncrop areas 251
pastures 97
small grains 97
sorghum 67
soybeans 67
vegetable crops, commercial 201

Control of specific weeds:

aquatic plants 257
brush 241
johnsongrass 111
shattercane 111
sorghum-almum 111

Field Crops and Livestock

Field Crops
& Livestock

1 Insect Pest Management for Field and Forage Crops

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Office of Agricultural Entomology
and the Illinois Natural History Survey

Intent of This Chapter

This publication addresses pest management guidelines for insects that attack field and forage crops in Illinois. Practical, *nonchemical control* measures that have proven effective are discussed and strongly encouraged. However, *insecticides* are often the only and most efficient tool for responding to insect pest outbreaks. We recommend that insecticides be used only to supplement a completely *integrated pest management* (IPM) program that also includes the use of cultural, mechanical, and biological control tactics.

IPM has been defined as the selection of management practices that promote favorable economic, ecological, and sociological outcomes. In this context, insecticides should be used only after all other effective insect control alternatives have been explored. Furthermore, insecticides should be used only when an insect population has reached or exceeded an *economic threshold*—that level of a pest population when control should be implemented to prevent economic yield loss (projected cost of damage is greater than the cost of control). Then, before one makes a decision to use an insecticide, potential *risks and benefits* should be evaluated. Risks to human health and safety, as well as environmental risks, such as the potential for surface or groundwater contamination and wildlife destruction, should be carefully considered along with the economic benefits of insect control with insecticides.

The insect management practices that are discussed in this publication are based on research results from the Illinois Natural History Survey, the University of Illinois College of Agriculture, other land-grant universities, and the U.S. Department of Agriculture. Insecticides suggested for use have been registered by the U.S. Environmental Protection Agency (USEPA). The information within this publication is revised annually and is intended for use during the current calendar year only.

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

Contents

Information Resources 5
Principles of Insect Management 6
Integrated Pest Management 6
Economic Thresholds 7
Field Scouting 7

Pest Management Tactics 8
Cultural Control 8
 Crop Rotation 8
 Tillage 8
Biological Control 9
Host Plant Resistance 9
Insecticides 10

Management of Some Key Insect Pests 10
Alfalfa Weevils 10
Black Cutworms 11
Corn Rootworms 11
European Corn Borers 14
Potato Leafhoppers 17
Wireworms 17

Insecticides Specified in This Chapter 18
Insecticide Registration and Nomenclature 18
Insecticide Classification 18
Soil Insecticides and Seed Treatments 19
Insecticides and Wildlife 22

Tables
1. Thresholds for Corn Rootworm Beetles 14
2. Biological Insecticides for Field Crops 23
3. Soil Insecticides for Rootworm Control, Illinois, 1993 24
4. Insecticides for Field Corn 25
5. Insecticides for Soybeans 29
6. Insecticides for Alfalfa 31
7. Insecticides for Grain Sorghum 33
8. Insecticides for Small Grains (Barley, Oats, Rye, Wheat) 35
9. Insecticides for Grass Pasture 36
10. Insecticides for Noncrop Areas 36
11. Harvest Restrictions 37
12. Relative Toxicities of Commonly Used Agricultural Insecticides 39
13. Worker Reentry Periods in Fields Where Insecticides Have Been Applied 40

Information Resources

Information about publications and educational meetings dealing with insect management in field and forage crops is available from your nearest Extension office or from Extension Entomology, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820; (217) 333-6652.

Insect Fact Sheets

During revision of this chapter, information about several specific insects was deleted. However, recently revised fact sheets (designated by NHE numbers) that discuss nonchemical control methods and give descriptions of specific insects and their life history and biology have been prepared for most of the insects that attack field and forage crops in Illinois. Color picture sheets are also available in this series. Individual fact sheets and color picture sheets are $.25 each.

Field Crop Scouting Manual

The *Field Crop Scouting Manual* contains information relating to disease, insect, and weed identification; scouting techniques; and economic thresholds. Picture sheets and line drawings are provided for many diseases, insects, and weeds that affect field crop production. Alfalfa, corn, and soybean management guides to assist crop consultants in diagnosing pest problems throughout the growing season are also provided. This manual is available from Vocational Agriculture Service, 1401 South Maryland Drive, Urbana, IL 61801; (217) 333-3871.

Insect Management Alternatives

The series *Alternatives in Insect Management* describes insect management techniques that do not involve conventional insecticides. Although synthetic chemical insecticides provide many benefits to food production and human health, they also pose some hazards. In many instances, alternative methods adequately control insects and pose fewer hazards. The publications in this series discuss the characteristics and relative strengths and weaknesses of available alternatives. Currently available are Circular 1295, *Microbial Insecticides*; Circular 1296, *Botanical Insecticides and Insecticidal Soaps*; Circular 1297, *Insect Attractants and Traps*; and Circular 1298, *Beneficial Insects and Mites*. These four circulars are combined in North Central Regional Extension Publication 401, *Alternatives in Insect Management: Biological and Biorational Approaches*. These publications are available from the Office of Agricultural Communications and Education, 69 Mumford Hall, 1301 West Gregory Drive, Urbana, IL 61801; (217) 333-2007.

Pest Management & Crop Development Bulletin

The *Pest Management & Crop Development Bulletin* is issued weekly during the growing season and as needed during the remainder of the year (25 issues annually). This series of newsletters provides a timely look at the agricultural insect, weed, plant disease, and crop development situation, along with suggested control measures. New developments in pesticide application are also included. To subscribe to this informative newsletter, contact the Agricultural Newsletter Service, 116 Mumford Hall, 1301 West Gregory Drive, Urbana, IL 61801; (217) 333-2666.

Illinois Agricultural Pesticides Conference

The Illinois Agricultural Pesticides Conference is held annually in early January on the campus of the University of Illinois. The conference deals with current issues surrounding the use of agricultural pesticides and encourages the proper, timely, and wise use of pesticides within an integrated crop management system. It is a public meeting for anyone in agriculture who has an interest in using pesticides in a crop pest management program.

Printed proceedings from this conference are available from Extension Entomology (see address and telephone listed previously). This 200-page reference contains about 40 articles concerning recent research information about insect, weed, and plant disease management and about recent advances in pesticide application technology.

Illinois Crop Protection Workshop

The Illinois Crop Protection Workshop is an annual program (March 3 to 5 in 1993) that provides the latest crop management information to agronomists, agrichemical representatives, county Extension advisers, crop consultants, farmers,

Information Resources (cont.)

farm managers, pesticide dealers and applicators, seed company representatives, soil conservationists, and anyone who has an interest in agricultural and environmental issues. Specialists provide in-depth discussions, educational materials, and "hands-on" exercises in specialized sessions regarding the biology and pest management strategies for insect, weed, and disease problems that occur in Illinois crops. General sessions provide challenging and far-ranging topics that affect a large cross section of those involved in agriculture.

Field Crop Pest Management Short Course

The Field Crop Pest Management Short Course is an annual program (March 8 and 9 in 1993) designed to train personnel who will be monitoring field crops for diseases, insects, and weeds. The latest scouting procedures and field sampling techniques are discussed by specialists from each of the pest management disciplines. Pest identification, plant injury symptoms, and economic thresholds are discussed in detail in a laboratory setting. A general session provides information on nutrient deficiency problems, as well as a discussion on the growth and development of corn and soybeans.

Pesticide Applicator Training Clinics

Commercial pesticide applicator training and certification clinics are offered annually at several locations throughout Illinois. Training for the General Standards exam and several commercial applicator categories are offered for applicators seeking to become certified. University of Illinois personnel provide the training and updates, and representatives from the Illinois Department of Agriculture oversee the testing. Study guides for the General Standards category and most of the commercial applicator categories are available at each clinic and through the nearest Extension offices or Extension Entomology. Contact Extension Entomology (see address and telephone listed previously) for information about dates, times, and locations for the various clinics.

Principles of Insect Management

Successful management of insect pests in field crops requires many decisions. These decisions should reflect the interests of the producer and preserve the integrity of the environment, and they may be very complex. Populations of insects (both beneficial and injurious species), weeds, and plant diseases interact with one another and the crop, and all are affected by the abiotic (nonliving) component of the environment. Considering the bewildering complexity of crop production practices such as tillage, crop rotation, cover crops, crop variety, and soil fertility, careful planning and considerable information are necessary for understanding how crop production decisions influence pest populations.

Integrated Pest Management

Weeds, plant diseases, and certain insects are pests because they compete with humans for food and fiber. Although the use of pesticides has become a standard practice for reducing pest populations, certain problems arise from sole reliance on pesticides. Because of concerns regarding insecticide resistance, secondary pest resurgence, and threats to the environment and public health in the 1960s and 1970s, the philosophy of integrated pest management (IPM) originated. In the 1990s, concerns about groundwater contamination, pesticide residues in food, and other pesticide-related issues continue to focus attention on the need for judicious use of pesticides. More than ever, IPM methodologies are vital for both a sustainable national agriculture and environmental protection.

Insect populations in field crops are governed by the same fundamental ecological principles that influence interactions of plants and animals in natural ecosystems. Agroecosystems have much less diversity of species than a forest or a prairie. Consequently, a field crop is more susceptible to a pest outbreak because of this lack of variety of plants and animals. The quick and often unpredictable alterations inflicted by changing weather and crop production practices can also trigger sudden changes in a pest's population.

IPM programs promote favorable economic, ecological, and sociological outcomes. In order to accomplish this challenging goal, agricultural scientists promote modification or management of the life systems of insects, weeds, and plant diseases. As the term "integrated" implies, this objective is reached by blending pest management tactics (see page 8).

Economic Thresholds

Effective management of an insect pest population requires a thorough understanding of the insect's life cycle and biology, as well as its potential to cause economic loss. People who use this knowledge to reduce an insect's population below a certain threshold are practicing applied ecological management.

Appropriate scouting techniques, proper identification of pests and beneficial insects, and instituting control measures when thresholds are reached are fundamental components of a sound IPM program. The economic threshold (ET) is that level of an insect population that indicates that control tactics should be used to stop a pest population from increasing further, thereby preventing economic losses. Economic thresholds may be expressed as numbers of insects—average number of bean leaf beetles per foot of row—or as a level of damage—5 to 10 percent of soybean pods injured within a field. A pest density that is sufficiently high to cause economic damage to a crop is called the economic injury level. The economic threshold is often referred to as the "action threshold" because control measures are usually employed when the insect population reaches this level to prevent pests from reaching the economic injury level.

Many years of research are required before defined economic thresholds can be developed. Most currently used thresholds are simplistic and do not incorporate densities of multiple pests into the decision-making process. More comprehensive decision-making processes should incorporate not only densities of multiple pests but also plant stresses (moisture stress, nutritional deficiencies, compaction, and so forth) and agronomic practices.

Neither environmental nor economic conditions are stable, so several factors may alter an economic threshold: (1) value of the crop (as the price paid for the crop increases, the economic threshold decreases), (2) cost of control (as the cost of control increases, the economic threshold also increases), and (3) crop stress (as the amount of stress on a crop increases, the economic threshold may decrease). For example, an insecticide may be economically justified for an insect pest population that is below the economic threshold if the crop is under stress from a lack of moisture, severe weed pressure, a plant disease, or a lack of proper fertility. Economic thresholds should be adjusted to reflect changes in market prices, cost of control, and crop stress.

To make use of economic thresholds and economic injury levels, some knowledge of the average population density of insects over time is required. Many insects are not pests because their populations in cultivated crops never reach a level sufficiently high to cause an economic loss. Occasional pests reach the economic injury level only when environmental conditions favor an increase in the pest's density. For example, hot and dry weather favors outbreaks of spider mite populations. Other insect pests are perennial, that is, their economic injury level is not much greater than their average population density. Certain agricultural pests belong in this category and, therefore, require carefully designed integrated management programs to keep their numbers below the economic injury level.

Although extensive research is required to develop comprehensive economic thresholds, lack of these thresholds should not discourage producers from beginning an IPM program. Simple action thresholds can serve as realistic guidelines for making insect management decisions and may prevent needless applications of pesticides.

Field Scouting

Regular monitoring of crops is necessary to determine population densities of both beneficial and potentially harmful species. From both economic and environmental perspectives, a successful pest management program depends on these population estimates. Pest scouting has been accepted and implemented by many Illinois farmers, and scouting programs are currently offered by private consulting firms, farmer cooperatives, pesticide dealers, and seed companies throughout the state.

It is important to conduct representative surveys of a field and, upon completion, have an accurate indication of the number, kind, and severity of pest problems present. A field is a unit of land that has been treated the same way agronomically (same planting date, same variety, same crop rotation, same fertility level, etc.). For example, if a 40-acre field has been planted to two corn varieties, 20 acres devoted to each variety, the two 20-acre units should be scouted as if they are different fields. Fields should be scouted at least once a week; inspections should be made in several representative areas of each field. Avoid scouting the edges of a field unless specifically looking for an insect that first invades field edges (grasshoppers, spider mites, stalk borers). Accurate records of each scouting visit are very important.

A producer should answer the following questions when thinking about implementing a scouting program or hiring a crop consultant: (1) Do you have the time to scout? (2) Do you know how and when to scout? (3) Can you identify insect pests? (4) Can you identify beneficial insects? (5) Can you accurately sample insect populations, at least well enough to feel comfortable with your decisions? (6) Can you accurately measure crop damage? (7) Do you know and understand economic thresholds? (8) Are you aware of all of the insect control alternatives? and (9) Can you prepare a thorough set of crop scouting records? If a producer answers no to most of these questions but wants to begin an active IPM program, the services of a professional crop consultant should be considered. Producers can also enroll in educational IPM programs offered by the Cooperative Extension Service to learn about current crop monitoring techniques and IPM tactics.

Pest Management Tactics

Cultural Control

Crop Rotation

Crop rotation greatly influences whether a soil insect problem may occur. The complex of insect pests changes according to the type of crops rotated, the sequence of the crop rotation, and the amount of time devoted to the production of a particular crop prior to planting a new crop. The brief summaries that follow should help producers determine the likelihood of an insect outbreak in different crop rotation schemes.

Corn after Soybeans

The potential for soil insect problems in corn after soybeans is generally low, and the use of a soil insecticide is not recommended. A lindane or diazinon + lindane planter-box seed treatment will be adequate to protect the seeds from seedcorn beetles, seedcorn maggots, and wireworms.

Corn after Corn

The potential for rootworm damage exists wherever corn is planted after corn in Illinois. A rootworm soil insecticide may be needed in these fields.

Corn after Legumes

Cutworms, grape colaspis, white grubs, and wireworms occasionally damage corn planted after clover and alfalfa and adult northern corn rootworms are sometimes attracted to legumes or to weed blossoms in legumes for egg-laying, especially in years when beetles are forced to leave adjacent fields of drought-stressed corn to seek food. The use of a seed treatment is recommended, but producers may consider the use of a soil insecticide for this cropping sequence.

Corn after Small Grain

There is a slight potential for damage by wireworms, seedcorn beetles, and seedcorn maggots in corn after small grain, particularly wheat. In most instances, a diazinon + lindane planter-box seed treatment is adequate. However, excessive weed cover in small-grain stubble may have been attractive to northern corn rootworm beetles for egg-laying if the beetles moved from adjacent fields of drought-stressed corn.

Corn after Grass Sod

Corn billbugs, sod webworms, white grubs, and wireworms may cause stand reductions when corn is planted after bluegrass, brome, fescue, rye, or wheat. If a producer decides to plant corn into an established field of grass sod, an insecticide, applied either before or at planting, should be considered for the control of wireworms and white grubs. Rescue treatments applied after the damage is noticed are not effective. If a stand is being severely thinned by wireworms or white grubs, the only options are to accept the reduced stand or replant and apply an insecticide during the replanting operation.

Corn after Sorghum

A planter-box seed treatment of diazinon or diazinon + lindane will protect the seeds from seedcorn maggots.

Tillage

The type of equipment and the timing (fall or spring), depth, and frequency of tillage operations can dramatically influence the survival of some insect species. Tillage operations may alter soil temperature, soil moisture, aeration, organic matter content, and bulk density of the soil, each of which may have a direct effect on some insects' survival and development. Often of greater importance to an insect population are the indirect effects occasionally associated with certain tillage systems. For example, poor weed management in some tillage systems enhances the likelihood of an increase in specific insect populations (black cutworms, stalk borers). However, sweeping predictions about how all insects respond to a certain tillage practice are not appropriate. Insect biologies vary among species, as do their responses to various tillage practices, crop rotations, and cover crops.

Insects that may cause problems in mulch till, ridge till, or no-till corn can be divided into two categories: soil insects and foliage-feeding insects. The insects most affected by changes in tillage practices are those that overwinter in the soil and become active during the early stages of crop growth. Soil- and litter-dwelling insects are affected more than the foliage-feeding insects. In most instances, a greater diversity of insects is present with reduced tillage, but this greater diversity does not always result in predictable increases or decreases in crop damage because both pests and their natural enemies respond to tillage practices.

The soil insect complex includes billbugs, corn rootworm larvae, cutworms, seedcorn beetles, seedcorn maggots, white grubs, and wireworms. Foliage-feeding insects include armyworms, brown and one-spotted stink bugs, European corn borers, hop vine borers, and stalk borers. These insects are not unique to conservation tillage systems, but they are the ones that will most likely be affected by changes in tillage practices. Systematic scouting to identify and quantify the pest problems is an important tactic for gathering information for effective pest management programs and should be given high priority.

By comparison with research efforts on corn insects, much less research has focused on the influence of various cultural practices on insect populations in soybeans. Most soybean insect pests are defoliators or pod feeders. They are often very mobile; some immigrate from other regions of the country, and most move readily from field to field. The effect of a single soybean producer's tillage practices on the potential for damage caused by defoliators is insignificant.

Although the effects of different tillage practices on insect pests in soybeans should be considered when planning an insect management program, management strategies need not be altered in most situations. Regardless of the tillage practice employed, foliage-feeding insects should be monitored regularly throughout the season. Established economic thresholds are available for defoliating insects. With the exception of seedcorn maggots and, occasionally, white grubs, soil insects rarely cause economic damage to soybeans.

Slugs occasionally cause significant injury to no-till soybeans. Slug populations are often highest in no-till systems where crop residue is greatest and lowest when no residue is present. Slug problems are expected to increase as conservation tillage becomes more common because of the residue cover and inclusion of soybeans in no-till rotational systems.

For more detailed information about the effects of tillage practices on insect populations, refer to Chapter 2 of the *Illinois Agricultural Pest Control Handbook,* "Alternatives in Insect Management: Field and Forage Crops."

Biological Control

Through a process called "natural control," certain insects and diseases suppress populations of pest insects without our help. For example, European corn borer populations are often reduced by *Beauveria bassiana,* a fungus, or by *Nosema pyrausta,* a protozoan. These diseases are part of the natural ecosystem and exert their influence without human intervention.

Through a process more appropriately called "applied biological control," predators, parasitoids, or disease pathogens are introduced artificially into the agroecosystem. Although considerable research has been conducted, the introduction of beneficial insects and disease pathogens into corn and soybean fields to control pest insects has not been very effective. Field crop environments change constantly, so beneficial organisms have a difficult time becoming established. Success stories in applied biological control are most often associated with more stable environments, such as forests. Although the practicality of releasing predators, parasitoids, or insect pathogens has not been demonstrated in row crops in the Midwest, we should continue to explore promising opportunities.

The use of microbial insecticides offers considerably more potential within an IPM program (see Table 2). Microbial insecticides are made of microscopic living organisms (viruses, bacteria, fungi, protozoa, or nematodes) or the toxins produced by them. These insecticides can be formulated to be applied as sprays, dusts, or granules. The chief advantage that microbial insecticides offer is their extremely low toxicity to nontarget animals and humans. Dipel 10G and Dipel ES are different formulations of a microbial insecticide that contains spores and the crystalline endotoxin of the bacterium *Bacillus thuringiensis kurstaki (Bt),* a bacterium effective only against the caterpillar stages of moths and butterflies. Both formulations of Dipel are registered and provide effective control of first-generation European corn borers. *Bt* products are useful for controlling European corn borers in fields where worker safety or the safety of people in residential areas is a primary concern. The use of *Bt* products in seed production fields where detasselers are working makes good sense.

For more detailed information about predators, parasitoids, pathogens, and microbial insecticides, refer to Chapter 2 of the *Illinois Agricultural Pest Control Handbook,* "Alternatives in Insect Management: Field and Forage Crops."

Host Plant Resistance

Most farmers in Illinois choose crop varieties primarily according to their yield potential and the time required to reach maturity. Although resistance to pathogens may determine the selection of a particular variety, only rarely is resistance to insects considered. However, certain varieties of field crops offer some level of resistance or tolerance to specific insect pests. For example, different corn hybrids have different degrees of tolerance or resistance to leaf feeding by first-generation European corn borers and sheath-collar feeding by second-generation borers. Resistant or tolerant varieties can also be found for the following insects: corn rootworms in corn; bean leaf beetle, Mexican bean beetle, potato leafhopper, and two-spotted spider mite in soybeans; Hessian fly in wheat; and alfalfa weevil, aphids, and potato leafhopper in alfalfa.

As a first step in managing insect pests in field crops, consider resistance or tolerance when selecting crop variety. At the very least, solicit from your seed dealer information about your selected variety and its ability to resist or tolerate insect infestations.

For more detailed information about host plant resistance to insect pests, refer to Chapter 2 of the *Illinois Agricultural Pest Control Handbook*, "Alternatives in Insect Management: Field and Forage Crops."

Insecticides

After thoroughly considering various nonchemical IPM tactics, field scouting techniques, economic thresholds, and the likelihood of an insect outbreak, a producer must weigh the risks and benefits of an insecticide application. Each year a farmer must estimate the potential for insect pests to cause economic loss before deciding whether to apply an insecticide. If the odds are very high that a certain insect will cause an economic loss in most years, a producer is likely to use a preventive insecticide application. This is often the tactic selected for control of soil insects like corn rootworms in continuous corn. Following are some key factors that a grower must consider to determine the probability of an insect outbreak: (1) crop rotation; (2) nature of insect problems over the years (perennial or occasional); (3) type and timing of tillage practices; (4) density of overwintering insect population; (5) density of spring weed populations and, for certain insect pests, the population of weeds in the fall; and (6) weather.

A producer who decides to use a preventive insecticide application should ask several questions:

- Is the insect you want to control listed on the insecticide label?

- Does the label state that the insecticide will control the insect, or does the phrase "suppression" or "will control low to moderate populations" appear?

- Will the insecticide selected provide acceptable control of the insect? Are you familiar with university research and recommendations?

- Is the recommended rate of application economical for your operation?

- Where should you place (band, furrow, broadcast) the insecticide to control the insect?

- How toxic is the insecticide to be used? Is it a restricted-use insecticide?

- Should you use a granular or liquid formulation?

- Will the insecticide pose potential hazards to the environment? If so, are there alternatives?

Many producers rely very successfully on field scouting, thresholds, and application of "rescue" insecticide treatments for certain insect pests as part of their overall farm management program. This approach works very well for black cutworms. Producers are made aware of the intensity of black cutworm moth flights in their counties and are provided with scouting information and projected dates of cutting damage. If cutworms reach damaging levels, postemergence applications of insecticides are effective.

Management of Some Key Insect Pests

Alfalfa Weevils

Numbers of alfalfa weevils are regulated to a large extent by winter weather. During a cold, open winter, the mortality rate is high in overwintering weevil populations; during mild winters, the mortality rate is low.

Parasitic wasps and a fungal disease may regulate weevil numbers in the spring. Although the wasp and the fungus will be present in alfalfa fields in 1993, we cannot yet predict their effect on weevil numbers. In general, wet weather promotes the spread of the fungal disease throughout the weevil population.

Alfalfa growers in southern and central Illinois should inspect their fields closely in April, May, and June. Early larval damage appears as pinholes in the growing terminals. As the larvae grow, they skeletonize the leaves, and damaged fields appear tattered. Growers in northern Illinois should look carefully for larval damage in May and June. Treatment may be warranted when growers find two to three larvae per stem and 25 to 40 percent of the tips are being skeletonized, depending on the height of the crop.

All growers should examine the stubble after the first cutting of alfalfa has been removed. Surviving larvae and newly emerged adults will feed on the crown and stem buds and either delay or prevent regrowth. Control may be warranted after a cutting when larvae and adults are feeding on more than 50 percent of the crowns and regrowth is prevented for 3 to 6 days.

Black Cutworms

Certain factors favor black cutworm outbreaks, especially late planting and the development of preplant weed infestations. Fields that are tilled and planted late are more likely to develop a preplant weed infestation than fields that are planted early. These late-planted fields with weeds are more attractive to cutworm moths as egg-laying sites.

Currently, two options are available for cutworm control: applications of soil insecticides to prevent damage and rescue treatments after the infestation appears.

Because of the uncertainty in predicting which fields will have light, moderate, or heavy infestations of cutworms, we encourage the use of rescue treatments for cutworm outbreaks rather than applying a preplant or planting-time treatment unnecessarily.

Based on the relatively low incidence of cutworm problems over the past 30 years, a grower should find an economic advantage to the wait-and-see system, which involves field scouting rather than a costly always-apply program in which a soil insecticide is routinely applied at or before planting for a problem that may not exist.

Rescue (or Emergency) Treatments

A key to effective cutworm control with rescue treatments is the amount of soil moisture. Control may be poor, regardless of the insecticide used, if the topsoil is dry and crusted and the worms are working below the soil surface. When the soil is dry, the higher recommended rates of the insecticides should be considered.

To determine the need for rescue treatments, scout the fields during plant emergence, particularly those fields considered to be high-risk. Early detection of leaf-feeding or of cutting by cutworms is vital. When the corn plants emerge, check the fields for leaf-feeding, cutting, wilting, or missing plants. Small cutworm larvae (less than 1/2 inch) feed on the leaves and do not cut plants until they are about half-grown.

A control measure may be needed if 3 percent or more of the plants are cut and cutworms are still present. A single cutworm will cut three or four plants if the plants are in the two-leaf stage or smaller. After corn plants reach the four-leaf stage, a single cutworm will cut only one or two plants during the remainder of its larval stage.

Corn Rootworms

The potential for rootworm damage to corn following corn is greatest in the northern two-thirds of the state. However, moderate to severe damage to corn roots may occur in any field where corn follows corn in Illinois.

The abundance of rootworm beetles in a cornfield during the summer of 1992 will largely determine the potential for rootworm larval injury if corn is planted in the same field in 1993. Generally, if beetle numbers reached or exceeded 0.75 per plant at any time during late July, August, or September 1992, rootworm larvae may cause economic damage in that field in 1993.

However, if the field scouted in 1992 was corn after any crop other than corn, the threshold (beetles per plant) is lower. The ratio of female to male beetles in first-year corn is usually higher than in continuous corn. Females migrate more than males, so most of the beetles found in first-year corn are females. As a consequence, the threshold for determining whether to rotate away from corn or to use a soil insecticide in 1993 may be as low as 0.5 beetle per plant. (See the section titled "Scouting to Determine Rootworm Potential in 1994," page 14 in this chapter, for a discussion about adjusting thresholds for different plant populations.)

Fields of corn planted in June 1992 may have extensive rootworm damage if they are planted to corn again in 1993. During August and September, rootworm beetles are especially attracted to late-planted or late-maturing fields. Seeking fresh pollen and silks to feed on, the beetles lay millions of eggs in these fields. Planting the fields to a crop other than corn in 1993 is suggested.

Suggestions for Rootworm Management, 1993

Producers should seriously consider crop rotation as the first choice for rootworm management, particularly in fields with a high probability of rootworm damage. Other management tactics are application of a soil insecticide at planting or during cultivation and control of rootworm beetles to prevent egg-laying. A soil insecticide applied at planting is the predominant method of rootworm control in corn after corn.

Crop Rotation

Crop rotation is an extremely effective way to prevent damage caused by northern and western corn rootworm larvae. If feasible, do not grow corn 2 years in succession in the same field. First-year corn after soybeans generally does not require a soil insecticide for rootworm control.

Although rootworm beetles can be found in "clean" or weed-free soybean fields and may even lay a few eggs there, the number of eggs is not great enough to warrant the use of a soil insecticide on corn the following season. In a few instances, rootworm larval damage has occurred to corn planted after soybeans when the bean field had been heavily infested with volunteer corn or weeds during August of the preceding year. Adult northern and western corn rootworms were attracted to these fields to deposit eggs. As a result, root damage by larvae occurred the following season. Fields infested with 5,000 or more volunteer corn plants per acre in 1992 may warrant treatment for rootworm control in 1993 if they are planted to corn. Good weed control in soybeans usually prevents rootworm damage in corn after soybeans.

Corn rootworm beetles deposit the vast majority of their eggs in cornfields. The larvae cannot survive on the roots of broadleaf crops (soybeans or alfalfa) or broadleaf weeds. Consequently, when a crop other than corn—soybeans, for example—is planted in a field with soil containing millions of rootworm eggs, the rootworm larvae die from starvation.

Soil Insecticide Application at Planting

Certain granular soil insecticides can be applied at planting time to prevent damage by corn rootworm larvae. The granules should be applied directly over the row in a 7-inch band ahead of the planter press wheel or firming wheels and incorporated with spring tines or drag chains mounted behind the planter units. Some insecticides can also be applied in the seed furrow, but others are not labeled for in-furrow application because they either won't provide adequate root protection or will cause seedling injury. Consult Tables 3 and 4 for recommended rates of application and proper placement.

Planting-time treatments applied in early April may provide only marginal root protection. Consider an application during cultivation in late May or early June in such fields, rather than a treatment at planting time.

Liquid insecticides that are labeled for rootworm control can be used by growers who do not have granular applicator attachments on their planters. These products are highly toxic, so use extreme caution when handling them. Liquid insecticides may be mixed with water and applied as a spray in a 7-inch band ahead of the press wheels, or they may be mixed with liquid fertilizer and used with a split-boot applicator at planting. However, *incompatibility or crop injury* may be a problem with combinations of a liquid insecticide and a liquid fertilizer. Conduct a test before planting to make certain that the two are physically compatible. Maintain agitation in the tank after mixing and during application to prevent separation. Consult Tables 3 and 4 for recommended rates of application and proper placement.

The rates suggested in Table 3 should not be exceeded for rootworm control. Research has shown that increasing the rates of soil insecticide application does not improve the level of root protection. Increasing the rate of application will not solve rootworm control problems and may accelerate the onset of resistance in the rootworm population.

Proper calibration, placement, and incorporation of rootworm soil insecticides will improve the likelihood of effective root protection. See the section titled "Calibration for Granular Soil Insecticides," page 19 in this chapter.

Reduced Rates of Soil Insecticides for Rootworm Control

Results from on-farm experiments in northern Illinois during 1990 and 1991, along with findings generated from university trials conducted throughout the Midwest for several years, led Extension entomologists at the University of Illinois to the following conclusions:

- Reduced application rates (25 percent reduction) of several commonly used insecticides provide equivalent root protection to the labeled rates based upon results from university trials and on-farm experiments.

- When reduced application rates fail to provide adequate root protection, performance of the insecticide applied at the labeled rate is typically also poor.

- Producers who calibrate their planters to deliver soil insecticides precisely at the reduced rate (25 percent reduction) can achieve root protection comparable to the labeled rate.

- Producers who are interested in trying reduced application rates should not reduce rates by more than 25 percent.

- Producers should leave a check or an untreated area (no insecticide used) in any field where an insecticide is used at either the labeled or reduced rate. This will enable producers to make a valid comparison of root injury in treated and untreated areas of a field. This is the only method by which the root protection afforded by an insecticide can be judged adequately.

• Producers should scout their cornfields (devoted to continuous corn production) for rootworm beetles each summer to determine the need for a soil insecticide the following year at planting. In 1991, 79 percent (23 fields) of the on-farm experiments would not have required any insecticide application at planting.

• *Farmers assume all legal responsibility for the use of any insecticide applied at a rate lower than the labeled rate.*

Suggestions for Alternating Rootworm Soil Insecticides

Avoid using the same soil insecticide for several consecutive years. The continuous use of one insecticide may enable soil microorganisms to break it down more rapidly or may hasten the onset of insecticide resistance. *Illinois entomologists encourage growers to alternate rootworm soil insecticides* following these suggestions:

• If performance of a soil insecticide has been poor in a particular field in recent years, do not use the same insecticide in that field in 1993.

• Avoid using carbamates in consecutive years.

• Avoid using the same organophosphate or pyrethroid for several consecutive years.

Soil Insecticide Application at Cultivation

A soil insecticide can be applied during cultivation either as an alternative to a planting-time application or as a "rescue" treatment if the planting-time insecticide fails to protect the roots from rootworm larvae. In either case, you should dig up several plants and examine the roots and surrounding soil for rootworm larvae and injury. If you find three or more larvae per plant and the field was not treated at planting, a cultivator application may be warranted. If the field was treated at planting and rootworm larvae and damage are obvious in June, you might want to apply a cultivator treatment. "Obvious" rootworm injury is characterized by brown root tips and roots that have been tunneled in or chewed back toward the base of the plant.

The insecticide should be applied on both sides of the row at the base of the plants just ahead of the cultivator shovels. Cover the insecticides with soil. The best time to apply a basal treatment of a soil insecticide at cultivation is usually in late May or early June if evidence of rootworm feeding damage is noted.

Soil moisture may affect both application and effectiveness of cultivation-time treatments. Fields that are too wet may never be cultivated. On the other hand, the insecticide may not perform satisfactorily if the soil is too dry.

Control of Rootworm Beetles to Prevent Egg-Laying

Research conducted during the mid-1970s indicated that properly timed sprays that prevent rootworm beetles from laying eggs eliminate the need for a soil insecticide the following year. However, the procedure requires supervision by properly trained pest management personnel. Beetle migration and certain weather conditions may minimize the treatment's effectiveness.

Two new products are being promoted for use in corn rootworm beetle suppression programs. Compel, marketed by Ecogen, and Slam, marketed by MicroFlo, both include cucurbitacin, a rootworm beetle feeding stimulant from buffalo gourd that has been ground to a powder. Compel is cucurbitacin plus a sticking agent; the product is combined with a very small amount of insecticide, usually carbaryl, just before application. Slam is a combination of cucurbitacin and carbaryl. Both work on the principle that when rootworm beetles encounter the cucurbitacin, they will begin feeding voraciously on the "bait" and will ingest a lethal dose of insecticide.

In research trials conducted during the past few years, these products have reduced rootworm beetle densities, but their ability to prevent egg laying, and consequently provide root protection for the next year, has not been consistent. The use of these "bait" products is still in an experimental and promotional phase. We urge caution if you wish to investigate their use. Conventional insecticides like Penncap-M and Sevin XLR Plus can also be used in rootworm beetle suppression programs, but recommended guidelines must be followed precisely if the program is to be successful.

The prerequisites for a successful beetle suppression program are very complex. One must be able to identify both species (western and northern), distinguish between the sexes, and determine whether the females are gravid (eggs present). Frequent scouting trips and precise scouting techniques are also requirements. For more specific information about this rootworm management alternative, contact the Extension entomologists at the University of Illinois.

Control of rootworm beetles to prevent egg-laying is an alternative to application of a soil insecticide at planting. Ideally, one properly timed spray should *replace* a soil insecticide. Unfortunately, some fields will require two sprays to combat extended beetle emergence and egg-laying. Two sprays or a spray plus a soil insecticide the following season may hasten the onset of rootworm resistance to insecticides.

Controlling rootworm beetles to prevent egg-laying and controlling beetles to prevent silk clipping do not overlap in time. Most eggs are laid from mid-August through early September, well after the time when treatments to prevent silk clipping would be necessary.

Summary: Planning Your Rootworm Management Program

A management plan for rootworms should be long-range (not a year at a time) and include crop rotation, insecticide rotation, cultivator treatments, and scouting to determine the need for rootworm control.

- Alternate corn with another crop when possible, particularly in fields where rootworm beetles averaged 0.75 or more per plant last summer, or if the soil insecticide did not adequately protect the roots in 1992.

- If you intend to grow corn after corn and if rootworm beetles averaged 0.75 or more per plant in corn after corn or 0.5 per plant in first-year corn last summer, apply a rootworm soil insecticide at planting time. Apply the rate suggested in Table 3 and consider our suggestions for alternating rootworm soil insecticides.

- Consider a cultivation-time application of a rootworm soil insecticide if you intend to plant in early April or if your planting-time insecticide does not provide adequate root protection.

- Scout for rootworm beetles in July and August 1993 to determine the potential for rootworm larval damage in 1994.

Scouting to Determine Rootworm Potential in 1994

The abundance of rootworm beetles in a cornfield in July and August is an indicator of potential rootworm problems the following year. You can determine the potential for rootworm damage in 1994 by counting western and northern corn rootworm beetles from mid-July through August 1993 in this way:

1. Scout weekly between mid-July and late August in fields that might be planted to corn again in 1994.

2. Examine two plants selected at random in each of 25 areas of the field. Count all of the western and northern corn rootworm beetles each time. The counts take about 45 minutes in a 40-acre field.

3. As you approach a plant, move quietly to avoid disturbing the beetles. Count the beetles on the entire plant, including the ear tip, tassel, leaf surface, and behind the leaf axils.

4. Record the number of beetles you find per plant. If the average is more than 0.75 beetle per plant in corn after corn or 0.5 beetle per plant in first-year corn for any sampling date, plan to rotate away from corn or apply a rootworm soil insecticide to corn in 1994. If populations do not exceed an average of 0.5 beetle per plant for any sampling date, a soil insecticide will not be needed the following season.

Table 1 shows the thresholds for different plant populations and cropping sequences. If the beetle count exceeds these thresholds, management of next year's larval population through crop rotation or insecticide application (corn following corn) is recommended.

Table 1. Thresholds for Corn Rootworm Beetles
Average number of beetles per plant for different plant populations and cropping sequences

Average number of plants per acre	Average number of beetles per plant	
	Continuous corn	First-year corn
14,000	1.4	1.0
16,000	1.3	0.9
18,000	1.1	0.8
20,000	1.0	0.7
22,000	0.9	0.6
24,000	0.8	0.6
26,000	0.8	0.5
28,000	0.7	0.5

European Corn Borers

Corn growers in the north central states have experienced economic infestations of European corn borers in recent years. Both first- and second-generation corn borers have caused yield losses in many areas of Illinois. The trend toward planting long-season corn varieties very early has probably contributed to larger populations of corn borers. When planted early, long-season hybrids can be attacked by the first generation and may still be attractive to the second generation. In addition, most reduced tillage systems, especially those that do not include plowing, permit increased survival of the overwintering population of borers.

Scouting and Decision-Making for First-Generation European Corn Borers

Scouting Procedure

Corn that is planted early (the fields with the tallest corn) should be monitored closely during June and early July for signs of whorl feeding by corn borer larvae. The fields with the tallest corn are the most attractive to moths that are laying eggs for the first generation.

Plan to scout cornfields for damage at least once a week for 2 to 4 weeks after initial corn borer moth flight, generally from early June to early July.

Grassy areas and soybean fields that border cornfields may harbor large numbers of corn borer moths because female moths rest in these areas during the day. Check these areas for moths before you enter the field to determine whether moths are present.

To determine whether an insecticide treatment is economically justified, examine 100 plants (10 consecutive plants at 10 different locations in a field, always avoiding field edges) for shot-hole feeding in the whorl leaves. At each location, unroll the whorl leaves of an infested plant (one with shot-hole feeding) and count the live corn borers. Calculate the percentage of plants infested and the average number of live borers per infested plant. Also note the location of the corn borer larvae. Those that are still in the whorl leaves can be controlled, while those that have bored into the stalk are protected from the insecticide. If all larvae have left the whorl leaves and bored into the stalk, treatments will not be effective.

Decision-Making

To decide whether it will be profitable to treat a field infested with first-generation corn borers, the following information is needed:

- average percentage of plants with whorl feeding
- average number of larvae per infested plant
- crop growth stage
- expected yield per acre
- anticipated value of grain per bushel
- cost per acre for insecticide treatment

Enter these data into the management worksheet for first-generation corn borers on page 16 to calculate the gain or loss if an insecticide is applied.

For best results, treatment should be applied soon after egg hatch to kill the young larvae before they bore into the plant. The larvae begin tunneling into the stalks about 10 days after hatching.

Scouting and Decision-Making for Second-Generation European Corn Borers

Scouting Procedure

Start checking for egg masses when moth flight is under way, usually from July through mid-August. Concentrate initial scouting efforts in late-planted fields where the probability of an economic corn borer infestation is greatest. Scout fields at least once a week, and continue scouting throughout the egg-laying period.

Grassy areas and soybean fields that border cornfields may harbor large numbers of corn borer moths because female moths rest in these areas during the day. Check these areas for moths before you enter the field to determine whether moths are present.

Examine a minimum of 50 plants, selected at random throughout the field, and count the number of corn borer egg masses found on each plant. Although 90 percent of the egg masses are laid on the ear leaf and the three leaves above and below the ear leaf, you should plan to examine all the leaves on each plant.

Decision-Making

To determine whether it will be profitable to treat a field infested with second-generation corn borers, the following information is needed:

- average number of European corn borer egg masses per plant
- crop growth stage
- expected yield per acre
- anticipated value of grain per bushel
- cost per acre for insecticide treatment

Because the egg-laying period of the second flight of moths is extended, you should accumulate egg counts for consecutive scouting trips. For example, if you find an average of 0.2 egg mass per plant on your first scouting trip and 0.4 egg mass per plant on your second scouting trip 5 days later, add the two counts together to determine the cumulative count. In this example, the cumulative count is 0.6 egg mass per plant.

Enter these data into the management worksheet for second-generation corn borers on page 16 to calculate the gain or loss if an insecticide is applied.

For best results, treatment should be applied soon after egg hatch to kill the young larvae before they bore into the plant. The larvae begin tunneling into the stalks about 10 days after hatching.

Management Worksheet for
First-Generation Corn Borer

_______ % of 100 Plants Infested x _______ Average No. Borers/Infested Plant = _______ Borers/Plant
(determined by checking whorls from 10 plants)

_______ Borers/Plant x _______ % Yield Loss/Borer* = _______ % Yield Loss

_______ % Yield Loss x _______ Expected Yield (Bu/A) = _______ Bu/A Loss

_______ Bu/A Loss x $ _______ Price/Bu = $ _______ Loss /A

$ _______ Loss/A x _______ % Control = $ _______ Preventable Loss/A
(80% for granules)
(50% for sprays)

$ _______ Preventable Loss/Acre – $ _______ Cost of Control/A =

$ _______ Gain (+) or Loss (–) per acre if treatment is applied

*5% for corn in the early whorl stage; 4% (late whorl); 6% (pretassel).

Management Worksheet for
Second-Generation Corn Borer

_______ Number of Egg Masses/Plant x 4 Borers/Egg Mass* = _______ Borers/Plant
(cumulative counts, taken 7 days apart)

_______ Borers/Plant x _______ % Yield Loss/Borer** = _______ % Yield Loss

_______ % Yield Loss x _______ Expected Yield = _______ Bu/A Loss

_______Bu/A Loss x $ _______ Price/Bu = $ _______ Loss/A

$ _______ Loss/A x 75 % Control = $ _______ Preventable Loss/A

$ _______ Preventable Loss/Acre – $ _______ Cost of Control/A =

$ _______ Gain (+) or Loss (–) per acre if treatment is applied

*Assumes survival rate of 20 percent (4 borers/egg mass).
**5% for corn in the early whorl stage; 4% (late whorl); 6% (pretassel); 4% (pollen shedding); 3% (kernels initiated). Use 3% per borer per plant if infestation occurs after silks are brown. The potential economic benefits of treatment decline rapidly if infestations occur after corn reaches the blister stage.

Potato Leafhoppers

Potato leafhoppers may cause moderate to severe injury to the second and third cuttings of alfalfa in all areas of Illinois. Injury first appears as a yellow, wedge-shaped area at the tip of the leaf. Many people confuse the injury with diseases or nutrient deficiency. Injury caused by potato leafhoppers can reduce both the yield and nutritional quality of the hay, and the effects of damage to one cutting can carry over to the next cutting or even into the next growing season. As a consequence, early detection of leafhoppers with a sweep net is extremely important.

Injury may begin on the new growth as soon as the first hay crop is removed. Stunting and yellowing are signs of leafhopper injury. A swarm of leafhoppers at the time of the first cutting also indicates that there may be a problem in the new growth. The economic threshold for leafhoppers varies with the height of the alfalfa (see Table 6). A treatment is justified when the number of leafhoppers exceeds the economic threshold.

Potato leafhopper populations are usually smaller in stands of alfalfa in which grasses are present. In addition, potato leafhopper densities are often reduced when alfalfa is intercropped with oats. The need for an insecticide application may be less in mixed stands of alfalfa and oats than in pure stands of alfalfa.

Soybean growers have noticed potato leafhopper injury in some fields of soybeans during years when leafhopper numbers are extremely large and adjacent fields of alfalfa are being cut. The injury to soybean leaves is similar in appearance to the injury on alfalfa leaves. The edges of injured soybean leaves turn yellow and then appear burned; injured leaves often curl and crinkle. Because the pubescence on most soybean varieties deters feeding by potato leafhoppers, leafhoppers seldom cause economic damage to soybeans. However, soybean varieties that have sparse or short leaf pubescence are susceptible to leafhopper feeding and subsequent damage.

For susceptible soybean varieties, control of potato leafhoppers in blooming soybeans may be warranted when you find 6 or more leafhoppers per plant. During early seed formation, control may be warranted if you find 13 or more leafhoppers per plant.

Wireworms

During the past few years, wireworm damage to corn has occurred with increasing frequency. Even so, usually less than 1 percent of the cornfields in Illinois are affected annually by wireworms, so the widespread use of soil insecticides on first-year corn after soybeans is not justified.

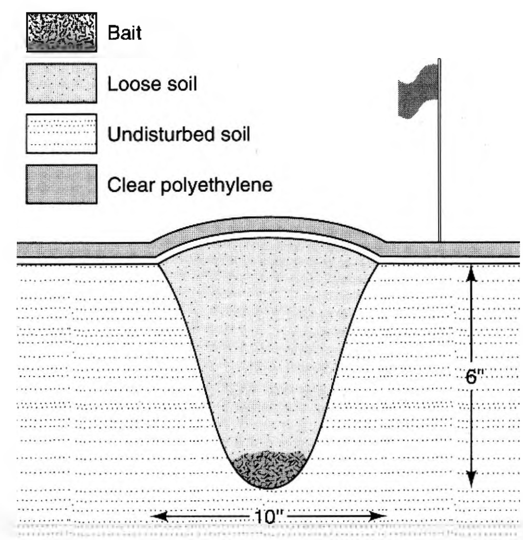

Figure 1. Cross section of a wireworm solar bait station.

Wireworms are usually most injurious in bottomlands or in poorly drained areas on upland soils. Low spots in the field often have the heaviest populations.

Attempts to control wireworms with an insecticide rescue treatment after the damage appears are not very successful. Therefore, if an infestation is present, an insecticide should be applied at planting. A lindane or diazinon + lindane planter-box seed treatment may deter the wireworms from attacking the seed but will not protect the seedling.

Checking for Wireworms

A baiting technique has been developed for evaluating the likelihood of a wireworm infestation before planting. The bait stations should be established 2 to 3 weeks before the anticipated planting date. Fields where small grain or grasses have been grown the preceding 2 or 3 years are the best candidates for bait stations.

Because wireworm infestations are usually not uniform within a field, bait stations should be placed randomly throughout the field. One bait station per acre is desirable. If you cannot place one station per acre, be sure that your baiting program adequately represents all areas of the field.

Follow this procedure for baiting:

1. Use a mixture of 1 cup of wheat and 1 cup of shelled corn at each station.

2. Bury the bait about 4 to 6 inches deep. It is also desirable to cover the ground over each bait station with an 18-inch square of clear plastic (see Figure 1). The plastic collects solar heat and speeds germination of the corn and wheat, which attracts overwintering wireworms.

3. Mark each station with a flag or stake.

4. Dig up the bait stations in 10 to 14 days and count the number of wireworms.

Need for Treatment

If you find an average of one or more wireworms per bait station, use a labeled soil insecticide. In some instances, several wireworms may be found in one bait station and none in others. Wireworm infestations tend to concentrate in some locations. It may be possible to limit treatment to areas where the concentration of wireworms is heaviest.

Insecticides Specified in This Chapter

Insecticide Registration and Nomenclature

The insecticides discussed herein are registered by the U.S. Environmental Protection Agency (USEPA). However, not all insecticides registered for control of crop insect pests are included. Effective insecticides that do not present an undue hazard to the user or the environment are suggested whenever possible. We urge you to note the telephone number of the Poison Information Control Center nearest you (Appendix A) and to follow the guidelines recommended in Appendix B when working with insecticides. Your safety depends upon it.

When this publication was prepared, only currently registered insecticides were included. New registrations and changes in registration, labels, and recommendations will be announced through the *Pest Management & Crop Development Bulletin*, appropriate media sources, and Extension advisers. Appendix C provides general information about special local needs and emergency registrations.

The USEPA has also taken measures to protect groundwater and endangered species. For details, consult Appendices D and E.

The chemical names used herein may be unfamiliar to you. These names are the common, coined chemical names and as such are not capitalized (for example, carbaryl). Trade names are capitalized (for example, Sevin). In the tables of suggestions for control, only the trade name is listed. In the table of harvest restrictions (Table 11), the trade names are listed first, with the common names in parentheses following the trade names.

Some generic insecticides are formulated and/or sold by numerous pesticide formulators and distributors. These include carbaryl, dimethoate, malathion, and phorate. However, names and formulations of these generic insecticides are diverse, so their inclusion in this chapter is limited. The most commonly available trade name and formulation of each insecticide are included in this chapter. This does not represent discrimination against other trade names and formulations of the same product. Producers are advised to discuss the availability of generic products with a pesticide dealer.

Insecticides suggested for use in field corn, soybeans, alfalfa, grain sorghum, small grains, grass pasture, and noncrop areas are listed in Tables 4, 5, 6, 7, 8, 9, and 10, respectively. Information regarding use rates and placement and timing of applications, as well as supportive comments, are also provided in the tables.

Insecticide Classification

The USEPA classifies pesticides for *general* or *restricted*-use.

Commercial applicators who apply restricted-use pesticides must be certified. Commercial applicators include persons applying pesticides for hire and governmental personnel, chemical company representatives, and others involved in demonstrational, regulatory, and public health pest control. Certification as a commercial applicator requires passing written examinations administered either by the Illinois Department of Agriculture or the Department of Public Health.

Private applicators (farmers) who use restricted-use pesticides for the purpose of producing any agricultural commodity on property owned, rented, or otherwise controlled by them or their employer, or as exchange labor (no compensation) on the property of another, must be certified by passing a written examination.

Certification via written exam and the issuing of permits or licenses are handled by the Illinois Department of Agriculture. Training programs for farmers (private applicators) and commercial pesticide applicators are conducted by the Cooperative Extension Service to prepare persons for certification. For additional information about training programs, consult your nearest Extension adviser.

Soil Insecticides and Seed Treatments

Approximately 33 percent (3.5 million acres) of the corn grown in Illinois is treated annually with soil insecticides. Soil insecticides are often used in corn production to prevent damage by subterranean insects such as corn rootworms, cutworms, seedcorn maggots, white grubs, and wireworms. Seed treatments protect corn and soybean seeds from attack by seedcorn maggots and wireworms. Both soil insecticides and seed treatments are applied as preventive measures because rescue treatments are often ineffective against subterranean insect pests. However, whenever possible, these applications should be made based on scouting information or on the frequency of occurrence of different pests in different cropping sequences. The use of soil insecticides as "insurance" against soil insect pests is strongly discouraged.

In order for soil insecticides to be effective against the target insect you wish to control, proper calibration before application and placement of the insecticide during application is very important. Both the rates of application and placement vary among different soil insecticides for control of the assorted soil insect pests. Tables 3 and 4 list the suggested rates of application and placement for the most frequently encountered soil insect pests of corn. However, before applying soil insecticides, consult the label to determine the appropriate rate and placement for the target pest.

Calibration for Granular Soil Insecticides

Calibrate the applicators for granular soil insecticides before the planting season begins. In some instances, poor control is caused by applying rates that are too low. Proper calibration will help avoid this problem and will prevent over-application. Most soil insecticide bags have a list of suggested settings for the particular model of applicator. The settings are based on planting speed. The *beginning settings* are helpful, but check your actual application rate under your own operating conditions.

Follow these steps for calibrating the applicator:

1. Calibration of granular applicators for soil insecticides is usually based on ounces of product needed per 1,000 feet of row. Consult the insecticide label or Table 3 for labeled rates for rootworm control. These rates are expressed in ounces per 1,000 feet of row and in pounds of product per acre.

2. Consult the label or manufacturer's recommendation for an approximate application setting. Adjust the setting on each hopper.

3. Select an area for a test run, preferably in the field so that speed and traction conditions are constant. Measure and mark off 1,000 feet.

4. Fill the hoppers and attach a plastic bag or container to each delivery tube to catch the granules from each hopper.

5. Drive the premeasured distance (1,000 feet) at the same speed to be driven during the planting operation.

6. Weigh the material collected from each hopper. Use a scale that weighs in ounces (e.g., a postal scale or a diet scale).

7. Compare the weight (ounces) per bag against the weights given in Table 3. The following amounts of material should be collected:

Formulation (percent)	Ounces collected per 1,000 feet
10	12
15	8
20	6

8. Recalibrate if the difference in the amount of insecticide applied during the calibration process is more than 10 percent over or under the rate suggested on the label.

Interactions Between Soil Insecticides and Herbicides

When properly applied as indicated on the labels, insecticides rarely cause phytotoxic symptoms of injury to field crops. However, certain combinations of soil-applied insecticides and herbicides can injure corn or soybeans. Two of these interactions are discussed.

Insecticide Interactions with Accent and Beacon

Beacon and Accent are postemergent corn herbicides that interact with organophosphate insecticides (see Table 12) resulting in injury to corn. The following label precautions, taken directly from pesticide labels, should be observed by producers.

Accent. DuPont's Accent label states: "Do not apply [Accent] to corn that has been treated within seven days before with foliar-applied organophosphate insecticides such as Lorsban, malathion, parathion, etc., . . . because severe crop injury may result. Do not apply any of these materials within three days after applying Accent or severe crop injury or antagonism may result. Do not apply [Accent] if crop was previously treated with Counter 15G (all application methods) as severe crop injury may result. Do not apply [Accent] if crop was previously treated with

Counter 20CR applied in furrow at planting or over-the-row at cultivation.

"Applications of Accent to crops previously treated with Counter 20CR applied in a band at planting on soils with less than or equal to 4% organic matter content may cause unacceptable crop injury. DuPont will not be held responsible for losses or damage resulting from such use.

"Applications to field corn treated with organophosphate insecticides such as Thimet, Dyfonate, Lorsban, etc., applied at planting or over-the-row at cultivation or with T-banded or surface banded Counter 20CR applied at planting on soils with greater than 4% organic matter content, may result in temporary crop injury.

". . . the use of Accent on popcorn or field corn grown for seed which has been treated with Counter insecticide is prohibited."

The Counter 20CR label states: "For field corn only. It is American Cyanamid Company's recommendation that Accent herbicide may be applied after banded applications of Counter 20CR. Applications of Accent herbicide following applications of Counter 20CR may result in temporary crop injury." Because results from research trials have not been consistent, and because we have observed injury when Accent is applied to corn that had been previously treated with Counter 20CR in a band, we encourage you to follow the directions and advice on DuPont's Accent label.

Beacon. The supplemental Counter 15G label states: "Counter 15G may be applied 7 days after application of Beacon herbicide. Please refer to at-cultivation directions. American Cyanamid Company does not recommend using Beacon herbicide following use of Counter 15G at planting." If other organophosphate insecticides (that is, Dyfonate, Lorsban, or Thimet) are applied at the time of corn seeding, temporary corn injury may occur following Beacon application. Do not apply a foliar postemergence application of an organophosphate insecticide within 10 days before or after Beacon application.

Insecticide Interactions with Sencor and Lexone

Labels of the metribuzin herbicides (Sencor and Lexone) indicate that injury to soybeans may occur when the herbicide is used in conjunction with soil-applied organophosphate insecticides. Organophosphate insecticides labeled for use on soybeans include chlorpyrifos (Lorsban), diazinon, ethoprop (Mocap), and phorate (Thimet). The combination of these insecticides and herbicides causes injury symptoms identical to the symptoms caused by metribuzin injury: plants are chlorotic; seedlings may die back; leaf margins and tips are scorched and turn yellow to brown; in severe cases, the entire leaf turns yellow to brown; and the stand may be spotty and uneven.

Prevention of this problem is simple: soil-applied organophosphate insecticides and metribuzin herbicides should not be applied in the same field. The insecticide apparently makes the herbicide more active, even when the herbicide is applied at the rate recommended on the label. This injury will most likely occur if poor-quality seed is planted or if the soybean seedlings are under environmental stress.

Granular Furadan Use Will Be Phased Out by 1994

FMC Corporation will phase out the sale and use of granular formulations of carbofuran (Furadan) for all but five minor uses by September 1, 1994. The phase-out concludes the special review of granular carbofuran conducted by the U.S. Environmental Protection Agency (USEPA). This review has been ongoing for the last six years and was assessed entirely upon perceived risk to birds. There was never an indication that human health problems could be attributed to granular carbofuran use. The phase-out does not affect liquid formulations of carbofuran.

The projected scenario for cancellation of labeled uses in Illinois is as follows:

1. Crop registrations for alfalfa stand establishment, grain sorghum, soybeans, and sunflowers will be canceled in Illinois beginning September 1, 1993.

2. Granular Furadan will no longer be sold as a labeled pesticide for corn beginning September 1, 1994.

FMC's agreement with the USEPA to phase out carbofuran granules also includes a USEPA review provision for corn and sorghum in the fall of 1993. The USEPA review will assess FMC information and comments from the public on the risks and benefits of these uses, and the USEPA may alter the planned program based on that input. The USEPA will also consider, on a case-by-case basis, requests for emergency uses under Section 18 and for special local needs under Section 24(c).

Carbofuran granules that are no longer in FMC's possession and are in the possession of distributors, dealers, and growers may be sold and used as labeled, even after the crop label expiration date. However, for corn and sorghum, the product may be used for only 1 year after the crop label expiration date.

In Illinois, Furadan 15G is the primary granular formulation of carbofuran labeled for control of certain insects and nematodes in corn, grain sorghum, soybeans, and sunflowers. Although Furadan 15G can still legally be purchased and used for control of insect pests in the aforementioned crops, we recommend that growers consider the use of alternatives. As stated elsewhere in this chapter, effective insecticides that do not present an undue hazard to the user or the environment are suggested whenever possible. Because USEPA has determined that the use of Furadan 15G presents an undue hazard to birds, its use should be discouraged in any situation where wildlife might be threatened. For all combinations of crops and pests for which Furadan 15G is labeled, alternative control measures are at least as effective as Furadan 15G.

Planter-Box Seed Treatments

Corn

Consider using a seed treatment in fields that will not be treated with a soil insecticide at planting time. A planter-box seed treatment containing diazinon will protect germinating corn against attack by seedcorn beetles and maggots. A lindane or diazinon + lindane planter-box seed treatment protects seed from attack by seedcorn maggots, seedcorn beetles, and wireworms. Follow the label directions for application. *NOTE:* Excess dust from the seed treater may interfere with the electronic monitor in air planters.

Some seed may have already been treated with a combination of insecticide and fungicide. Addition of diazinon + lindane may cause planter units to gum up. Consult your seed or insecticide dealer to obtain specific information about seed treatment combinations.

Soybeans

Consider using a diazinon or diazinon + lindane seed protectant to prevent damage to germinating soybeans caused by seedcorn maggots. Potential damage is greatest during cool, wet springs when germination is slow. Follow the label directions for application.

Insecticides and Wildlife

Concerns about pesticides contaminating or disrupting the environment have focused attention on certain uses of some insecticides. Several soil insecticides have been reviewed or are currently under special review by the USEPA. The primary concern regarding the granular formulations of these insecticides is their toxicity to birds. This same concern will probably trigger special reviews of other granular insecticides.

Several alleged bird kills have occurred shortly after planting-time applications of Furadan and other granular insecticides. Birds seeking food and grit apparently inadvertently ingest the insecticide granules and die from insecticide poisoning. It has been reported that predatory birds that feed on birds killed by insecticide poisoning may also be killed. We have also received reports of bird kills that occurred after foliar application of granular insecticides, particularly Furadan, for control of European corn borers.

We have stated previously that effective insecticides that do not present an undue hazard to the user or the environment are suggested whenever possible. As a consequence, we strongly recommend the use of Dipel or some other formulation (Biobit, Full-Bac, Javelin) of *Bacillus thuringiensis* for control of first-generation European corn borers. Ample research data indicate that *Bacillus thuringiensis* is just as effective for control of first-generation corn borers as the chemical alternatives, and it is nontoxic to birds, fish, or mammals. In situations where wildlife might be adversely affected by applications of chemical insecticides, an insecticide that contains *Bacillus thuringiensis* should be used. Although research data suggest that Dipel is not as effective as most chemical insecticides for control of second-generation corn borers, better timing of the application might improve its performance.

Although crop rotation is an excellent nonchemical alternative for planting-time applications of insecticides for rootworm control, producers who grow corn after corn have few nonchemical alternatives. The most prominent method of rootworm control in corn after corn is, and will continue to be, the application of granular soil insecticides at planting time. However, unincorporated granules on the surface of the soil may pose a threat to certain species of birds.

We strongly recommend that producers incorporate their granular insecticides with spring tines or chains mounted behind each planter unit. If incorporation is not possible and the selected insecticide is labeled for in-furrow application for the target insect, the insecticide should be applied in furrow. We also strongly encourage producers to shut off their insecticide delivery units before they turn around in the field's turn rows. Typically, when a planter is lifted out of the ground, open insecticide delivery units dribble insecticide granules onto the soil surface. These unincorporated granules pose a significant threat to birds that enter the fields during or just after the planting operation.

The threat to wildlife posed by insecticides can be reduced significantly in some instances and eliminated entirely in others. We urge producers to do everything possible to avoid insecticide applications and drift that pose undue hazards to wildlife, or to alter their insecticide applications in such a manner that the hazards are reduced to a minimum.

Table 2. Biological Insecticides for Field Crops

These products are highly selective insecticides specific for the control of lepidopterous larvae (caterpillars). Use them to control light to moderate populations of newly hatched worms in pest management programs. These insecticides must be ingested by the larvae to be effective. For consistent control, apply at first sign of newly hatched larvae (first and second instar). Susceptible larvae that ingest these insecticides cease feeding within a few hours and die within 2 to 5 days.

Insect	Insecticide[a]	Amount of product per acre	Placement	Comments
Alfalfa				
Alfalfa caterpillar	Biobit FC Dipel ES Javelin WG	1 to 3-1/2 pt 1 to 2 pt 1/4 to 1/2 lb	Broadcast Broadcast Broadcast	Apply as necessary to maintain control.
Webworms	Dipel ES	1 to 2 pt	Broadcast	Apply as necessary to maintain control.
Corn				
Armyworm	Biobit FC Javelin WG	2 to 7 pt 1/2 to 1-1/2 lb	Broadcast Broadcast	Use these products to control small armyworms (first and second instar) when populations are light and full coverage sprays are applied.
European corn borer (first generation)	Biobit FC Dipel ES Dipel 10G Dipel 10G Full-Bac Full-Bac Javelin WG	2 to 5-1/2 pt 1-1/2 to 2 pt 5 to 10 lb 10 lb 10 lb 7 to 10 lb 1 to 1-1/2 lb	Broadcast Over whorls Over whorls Broadcast Broadcast Over whorls Broadcast	Applications should be made when young larvae are present. One well-timed application against the first generation of larvae should provide economic control. Satisfactory control cannot be expected if treatment is delayed past the second instar or after larvae have begun entering the plant. Thorough spray coverage is needed to provide a uniform deposit at the site of larval feeding.
Fall armyworm	Dipel 10G Full-Bac	10 lb 10 lb	Over whorls Over whorls	Apply directly to corn whorls. Apply as necessary to maintain control.
Small grains				
Armyworm	Biobit FC Dipel ES Javelin WG	2 to 7 pt 1 to 4 pt 1 to 1-1/2 lb	Broadcast Broadcast Broadcast	Use these products to control small armyworms (first and second instar) when populations are light and full coverage sprays are applied.
Sorghum				
Corn earworm	Biobit FC Dipel ES	2 to 3-1/2 pt 1 to 2 pt	Broadcast Broadcast	Use these products to control small corn earworms (first and second instar) when populations are light and full coverage sprays are applied.

Table 2. Biological Insecticides for Field Crops (cont.)

Insect	Insecticide[a]	Amount of product per acre	Placement	Comments
Soybeans				
Corn earworm	Dipel ES Javelin WG	1 to 2 pt 3/4 to 1-1/4 lb	Broadcast Broadcast	Use these products to control small corn earworms (first and second instar) when populations are light and full coverage sprays are applied.
Cutworms	Biobit FC Javelin WG	2 to 5-1/2 pt 1/2 to 1-1/2 lb	Broadcast Broadcast	Apply as necessary to maintain control.
Green cloverworm	Biobit FC Dipel ES Javelin WG	2 to 3-1/2 pt 1 to 2 pt 1/4 to 1/2 lb	Broadcast Broadcast Broadcast	Apply as necessary to maintain control.

[a]There are different formulations for some of the insecticides listed. If you use a formulation other than the one listed in this table, *read the label* to determine the amount of product per acre.
ES = emulsifiable suspension; FC = flowable concentrate; G = granules; WG = wettable granules.

Table 3. Soil Insecticides for Rootworm Control, Illinois, 1993

Insecticide[a]	Time of application	Ounces of product per 1,000 ft of row	Amount of product needed per acre			
			40" rows	38" rows	36" rows	30" rows
*Counter 15G	At planting or cultivation	8	6.5 lb	6.9 lb	7.3 lb	8.7 lb
*Counter 20CR	At planting or cultivation	6	4.9 lb	5.2 lb	5.4 lb	6.5 lb
Dyfonate II 15G	At planting or cultivation	8	6.5 lb	6.9 lb	7.3 lb	8.7 lb
*Dyfonate II 20G	At planting or cultivation	6	5.0 lb	5.2 lb	5.4 lb	6.5 lb
*Force 1.5G	At planting	8-10	6.5–8.2 lb	6.9–8.6 lb	7.3–9.1 lb	8.7–10.9 lb
*Furadan 15G (see page 20)	At planting or cultivation	8	6.5 lb	6.9 lb	7.3 lb	8.7 lb
*Furadan 4F	At planting or cultivation	2.5 fl oz	2 pt	2-1/8 pt	2-1/4 pt	2-3/4 pt
Lorsban 15G	At planting or cultivation	8	6.5 lb	6.9 lb	7.3 lb	8.7 lb
Lorsban 4E	At cultivation	2.5 fl oz	2 pt	2-1/8 pt	2-1/4 pt	2-3/4 pt
Lorsban 4E	Preplant	Broadcast	6 pt	6 pt	6 pt	6 pt
*Thimet 15G	At planting or cultivation	8	6.5 lb	6.9 lb	7.3 lb	8.7 lb
*Thimet 20G	At planting or cultivation	6	4.9 lb	5.2 lb	5.4 lb	6.5 lb

*Use restricted to certified applicators only.
[a]Consult text for more information. *Liquid formulations are highly toxic.*

Table 4. Insecticides for Field Corn

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Armyworm (see Table 2)	*Ambush 2E *Asana XL Lorsban 4E *Penncap-M *Pounce 3.2EC Sevin XLR Plus	6.4 to 12.8 oz 5.8 to 9.6 oz 1 to 2 pt 2 to 3 pt 4 to 8 oz 2 to 4 pt	Broadcast	*Seedling corn*: Control is justified when 25% of the plants are being damaged. *After pollen shed*: Control is justified when the armyworms are eating leaves above ear level. Apply Ambush or Pounce prior to the brown silk stage.
Billbug	Lorsban 4E	2 to 3 pt	Broadcast	Apply as a postemergence rescue treatment. Use only ground equipment and apply 20 to 40 gallons of finished spray per acre.
Chinch bug	*Asana XL Lorsban 4E Sevin XLR Plus	5.8 to 9.6 oz 1 to 2 pt 2 to 4 pt	Spray at base of plant.	Treat border rows at the start of migration from small grains. Use only ground equipment and apply 20 to 40 gallons of finished spray per acre.
Corn earworm	*Ambush 2E *Asana XL Lannate 90WSP *Pounce 3.2EC	6.4 to 12.8 oz 5.8 to 9.6 oz 1/4 to 1/2 lb 4 to 8 oz	Overall spray or directed toward ear zone	Justified only in seed corn fields. Treatments are rarely effective for the control of earworms after worms enter ear tips.
Corn leaf aphid	Cygon 400 Lorsban 4E malathion 57%EC *Penncap-M	2/3 to 1 pt 1 to 2 pt 1-1/2 pt 2 to 3 pt	On foliage	Apply during late whorl to early tassel when 50% of plants have light to moderate infestations and plants are under drought stress.
Corn rootworm beetles	*Ambush 2E *Asana XL Cygon 400 Imidan 50WP Lorsban 4E *Penncap-M *Pounce 3.2EC Sevin XLR Plus	6.4 to 12.8 oz 5.8 to 9.6 oz 2/3 to 1 pt 1/2 to 1 lb 1 to 2 pt 1 to 2 pt 4 to 8 oz 2 pt	Overall spray or directed toward ear zone	To protect pollination, treat if there are five or more beetles per plant, pollination is not complete, and if silk clipping is observed. Apply Ambush or Pounce prior to the brown silk stage.
Corn rootworm larvae	*Counter 15G *Counter 20CR Dyfonate II 15G *Dyfonate II 20G *Force 1.5G	8 oz per 1,000 ft row 6 oz per 1,000 ft row 8 oz per 1,000 ft row 6 oz per 1,000 ft row 8 to 10 oz per 1,000 ft row	Band, furrow Band, furrow Band Band Band, furrow	At planting. Counter 15G and 20CR, Dyfonate II 15G and II 20G, Furadan 15G and 4F, Lorsban 15G and 4E, and Thimet 15G and 20G can also be applied at cultivation time.
	*Furadan 15G (see page 20) *Furadan 4F Lorsban 15G Lorsban 4E *Thimet 15G *Thimet 20G	8 oz per 1,000 ft row 2.5 fl oz per 1,000 ft row 8 oz per 1,000 ft row 6 pt 8 oz per 1,000 ft row 6 oz per 1,000 ft row	Furrow Band Band BC-PPI[c] Band Band	To minimize potential adverse effects to wildlife, producers should incorporate insecticide granules or apply the insecticide in-furrow (if labeled) and shut off insecticide units in turn rows.

Table 4. Insecticides for Field Corn (cont.)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Cutworms	*Ambush 2E	6.4 to 12.8 oz	PE[d]	Apply as a postemergence rescue treatment when 3% or more of the plants are cut and larvae are still present.
	*Asana XL	5.8 to 9.6 oz	PE[d]	
	Lorsban 4E	2 to 3 pt	PE[d]	
	*Pounce 3.2EC	4 to 8 oz	PE[d]	
	*Ambush 2E	6.4 to 12.8 oz	PRE[e]	These preventive treatments are probably best utilized in no-till corn where vegetation was plentiful during the cutworms' egg-laying period, or in fields that have to be replanted because cutworm damage to the original stand was severe. To minimize potential adverse effects to wildlife, producers should incorporate insecticide granules or apply the insecticide in-furrow (if labeled) and shut off insecticide units in turn rows.
	*Asana XL	5.8 to 9.6 oz	PRE[e]	
	Dyfonate II 15G	8 oz per 1,000 ft row	Band	
	*Dyfonate II 20G	6 oz per 1,000 ft row	Band	
	*Force 1.5G	8 to 10 oz per 1,000 ft row	Band, furrow	
	Lorsban 4E	1 to 2 pt	PRE[e]	
	Lorsban 4E	2 to 4 pt	BC-PPI[c]	
	Lorsban 15G	8 oz per 1,000 ft row	Band	
	*Pounce 1.5G	8 to 16 oz per 1,000 ft row	Band	
	*Pounce 1.5G	6.7 to 13.3 lb	PRE[e]	
	*Pounce 3.2EC	4 to 8 oz	PRE[e]	
European corn borer, first generation (see Table 2)	*Ambush 2E	6.4 to 12.8 oz	Broadcast	See Management Worksheet for First-Generation Corn Borer. Granular formulations are more effective than sprays when applied by air for control of first-generation borers. Sprays are most effective when directed by ground equipment over the row, rather than broadcast.
	*Dyfonate II 20G	4 to 5 lb	Broadcast	
	*Furadan 4F	1-1/2 to 2 pt	Broadcast	
	Lorsban 4E	1-1/2 to 2 pt	Broadcast	
	Lorsban 15G	5 to 6.5 lb	Broadcast	
	*Penncap-M	2 pt	Over whorl	
	*Penncap-M	4 pt	Broadcast	
	*Pounce 1.5G	6.7 to 13.3 lb	Broadcast	
	*Pounce 3.2EC	4 to 8 oz	Broadcast	
European corn borer, second generation	*Ambush 2E	6.4 to 12.8 oz	On foliage	See Management Worksheet for Second-Generation Corn Borer. Apply Ambush 2E or Pounce 3.2EC prior to the brown silk stage.
	*Dyfonate II 20G	5 lb		
	*Furadan 4F	1-1/2 to 2 pt		
	Lorsban 15G	5 to 6.5 lb		
	Lorsban 4E	1-1/2 to 2 pt		
	*Penncap-M	2 to 4 pt		
	*Pounce 3.2EC	4 to 8 oz		
	*Pounce 1.5G	6.7 to 13.3 lb		
Fall armyworm (see Table 2)	Lorsban 4E	1 to 2 pt	On foliage	Treat when 75% of plants have whorl damage and if worms are present. Ground sprays directed over the row are more effective than broadcast sprays. Treatments to control worms in ear tips are not effective.
Flea beetles	*Ambush 2E	6.4 to 12.8 oz	Over row as spray	When leaves on seedling plants are severely damaged and plants are being killed. For Lorsban, use only ground equipment and apply 20 to 40 gallons of finished spray per acre.
	*Asana XL	5.8 to 9.6 oz		
	Lorsban 4E	2 pt		
	*Penncap-M	2 to 3 pt		
	*Pounce 3.2EC	4 to 8 oz		
	Sevin XLR Plus	2 pt		

Table 4. Insecticides for Field Corn (cont.)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Grass-hoppers	*Asana XL Cygon 400 *Furadan 4F Lorsban 4E malathion 57%EC *Penncap-M Sevin XLR Plus	5.8 to 9.6 oz 1 pt 1/4 to 1/2 pt 1/2 to 1 pt 1-1/2 pt 2 to 3 pt 1 to 3 pt	On foliage	Treatment may be warranted when there are seven or more grasshoppers per square yard. After pollen shed, control is justified when grasshoppers are feeding on leaves above ear level. The higher rates are suggested for control of adult grasshoppers.
Japanese beetle	Sevin XLR Plus	2 to 4 pt	On foliage	During the silking period to protect silks if there are three or more beetles per ear and pollination is not complete.
Picnic, sap beetles	malathion 57%EC Sevin XLR Plus	1-1/2 pt 2 pt	On foliage	Justified only in seed corn fields when beetles are causing significant injury to ear tips.
Seedcorn maggots	diazinon diazinon + lindane	See label See label	On seed On seed	Use formulations that are prepared as seed treaters. Seed treatments should be considered for fields that do not receive a soil insecticide at planting. See label for proper disposal of treated seeds.
Sod webworm	Lorsban 4E	1 to 2 pt	Broadcast	Shallow incorporation using a rotary hoe or other suitable equipment immediately before or soon after treatment is necessary.
Spider mites	Cygon 400	1 pt	On foliage	Begin control if the majority of plants are infested with mites severe enough to cause some yellowing or browning of the lower leaves before dent stage.
Stalk borer	*Ambush 2E *Asana XL Lorsban 4E *Pounce 3.2EC	6.4 to 12.8 oz 5.8 to 9.6 oz 2 to 3 pt 4 to 8 oz	Broadcast	Apply postemergence sprays when young larvae are moving from weed hosts to corn. See labels for more specific instructions about effective control.
Thrips	malathion 57%EC	1-1/2 pt	On foliage	When severe wilting and yellowing of leaves are noticed.
White grubs	*Counter 15G *Counter 20CR *Force 1.5G Lorsban 15G Lorsban 4E *Thimet 15G *Thimet 20G	8 oz per 1,000 ft row 6 oz per 1,000 ft row 10 oz per 1,000 ft row 8 to 16 oz per 1,000 ft row 4 pt 8 oz per 1,000 ft row 6 oz per 1,000 ft row	Band, furrow Band, furrow Band, furrow Furrow BC-PPI[c] Band Band	At planting, if crop history and previous crop losses can be directly linked to a repeated history of grub problems. To minimize potential adverse effects to wildlife, producers should incorporate insecticide granules or apply the insecticide in-furrow (if labeled) and shut off insecticide units in turn rows.

Table 4. Insecticides for Field Corn (cont.)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Wireworms	*Counter 15G	8 oz per 1,000 ft row	Band, furrow	At planting, if crop history and/or bait stations indicate a potential for wireworm damage. To minimize potential adverse effects to wildlife, producers should incorporate insecticide granules or apply the insecticide in-furrow (if labeled) and shut off insecticide units in turn rows.
	*Counter 20CR	6 oz per 1,000 ft row	Band, furrow	
	*Force 1.5G	8 to 10 oz per 1,000 ft row	Furrow	
	*Furadan 15G (see page 20)	8 oz per 1,000 ft row	Furrow	
	*Furadan 4F	2.5 fl oz per 1,000 ft row	Furrow	
	Lorsban 15G	16 oz per 1,000 ft row	Band, furrow	
	Lorsban 4E	4 pt	BC-PPI[c]	
	*Thimet 15G	8 oz per 1,000 ft row	Band	
	*Thimet 20G	6 oz per 1,000 ft row	Band	
	lindane	See label	On seed	Use formulations that are prepared as seed treaters. See label for proper disposal of treated seeds.
	diazinon + lindane	See label	On seed	

*Use restricted to certified applicators only.
[a]See Table 11 for insecticide restrictions.
[b]The formulation of the product most commonly used in Illinois is listed. If you use another formulation, *read the label* to determine the amount of product per acre.
[c]BC-PPI = broadcast-preplant incorporated.
[d]PE = postemergent application.
[e]PRE = preemergent application.

Table 5. Insecticides for Soybeans

Spraying blossoming soybeans can be extremely hazardous to bees. Coordinate with local beekeepers before applying sprays. Beekeepers' names and colony locations may be obtained from your local Extension office.

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Bean leaf beetle	*Ambush 2E *Asana XL Cygon 400 Larvin 3.2F Lorsban 4E Orthene 75S *Penncap-M *Pounce 3.2EC Sevin XLR Plus	3.2 to 6.4 oz 5.8 to 9.6 oz 1 pt 18 to 30 oz 1 to 2 pt 2/3 to 1-1/3 lb 2 to 3 pt 2 to 4 oz 1 to 2 pt	On foliage	Seedlings: Treat if 20% of the plants are cut and the stand has gaps of 1 foot or more; or treat if at least one seedling per foot of row is destroyed. This level of damage usually requires 5 or more beetles per foot of row. *Before bloom*: When defoliation reaches 30% and there are 5 or more beetles per foot of row. *Bloom to pod fill*: When defoliation reaches 20% and there are 16 or more beetles per foot of row. *Seed maturation*: When 5 to 10% of the pods are damaged, the leaves are green, and there are 10 or more beetles per foot of row.
Blister beetles	Sevin XLR Plus	1 to 2 pt	On foliage	When defoliation reaches 30% before bloom and 20% between bloom and pod fill.
Corn earworm (see Table 2)	*Ambush 2E *Asana XL Larvin 3.2F Orthene 75S *Pounce 3.2EC	6.4 to 12.8 oz 5.8 to 9.6 oz 10 to 16 oz 1 to 1-1/3 lb 4 to 8 oz	On foliage	Damage occurs when larvae feed on pods. Apply control if populations exceed one per foot of row and 5 to 10% of the pods are damaged.
Cutworms (see Table 2)	*Asana XL Larvin 3.2F Lorsban 4E *Pounce 3.2EC	5.8 to 9.6 oz 20 to 30 oz 1 to 2 pt 2 to 4 oz	Broadcast	Scout as plants are emerging. Treat if 20% of plants are cut, stand has gaps of 1 foot or more, and cutworms are present.
Grasshoppers	*Asana XL Cygon 400 *Furadan 4F Lorsban 4E Orthene 75S *Penncap-M Sevin XLR Plus	5.8 to 9.6 oz 1 pt 1/4 to 1/2 pt 1/2 to 1 pt 1/3 to 2/3 lb 2 to 3 pt 1 to 3 pt	On foliage	When migration into fields begins and defoliation or pod feeding reaches economic levels. When defoliation reaches 30% before bloom and 20% between bloom and pod fill. When 5 to 10% of the pods are damaged. The higher rates are suggested for control of adult grasshoppers.
Green cloverworm (see Table 2)	*Ambush 2E *Asana XL Larvin 3.2F Lorsban 4E Orthene 75S *Penncap-M *Pounce 3.2EC Sevin XLR Plus	3.2 to 6.4 oz 2.9 to 5.8 oz 10 to 16 oz 1/2 to 1 pt 2/3 to 1-1/3 lb 2 to 3 pt 2 to 4 oz 1 to 2 pt	On foliage	When defoliation occurs during blooming, pod set, and pod fill. Usually requires 12 or more half-grown worms per foot of row and 20% defoliation to justify treatment.
Japanese beetle adults	*Asana XL *Penncap-M *Pounce 3.2EC Sevin XLR Plus	5.8 to 9.6 oz 3 to 4 pt 4 to 8 oz 1 to 2 pt	On foliage	When defoliation reaches 20% during bloom and pod fill.

Table 5. Insecticides for Soybeans (cont.)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Mexican bean beetle	*Ambush 2E *Asana XL Cygon 400 *Furadan 4F Larvin 3.2F Lorsban 4E Orthene 75S *Penncap-M *Pounce 3.2EC Sevin XLR Plus	3.2 to 6.4 oz 2.9 to 5.8 oz 1 pt 1/2 to 1 pt 18 to 30 oz 1 to 1-1/2 pt 2/3 to 1-1/3 lb 2 to 3 pt 2 to 4 oz 1 to 2 pt	On foliage	When defoliation reaches 30% before bloom and 20% between bloom and pod fill.
Potato leafhopper	*Ambush 2E *Asana XL Cygon 400 *Penncap-M *Pounce 3.2EC Sevin XLR Plus	3.2 to 6.4 oz 2.9 to 5.8 oz 1 pt 2 to 3 pt 2 to 4 oz 2 pt	On foliage	When leafhoppers are numerous and the edges of the leaves appear burned. For susceptible varieties, control in blooming soybeans may be warranted when 6 or more leafhoppers are found per plant. During early seed formation, control may be warranted if 13 or more leafhoppers are found per plant.
Seedcorn maggot	diazinon diazinon + lindane	See label See label	On seed On seed	At planting time. Use formulations that are prepared as seed treaters. See label for proper disposal of treated seeds.
Spider mites	Cygon 400 Dimethoate 400 Lorsban 4E	1 pt 1 pt 1/2 to 1 pt	On foliage	When symptoms of injury appear and mites are present.
Stink bugs	*Asana XL Lorsban 4E Orthene 75S *Penncap-M	5.8 to 9.6 oz 2 pt 1 to 1-1/3 lb 2 to 3 pt	On foliage	When adult bugs or large nymphs reach one per foot of row during pod fill.
Thistle caterpillar	*Pounce 3.2EC Sevin XLR Plus	4 oz 3 to 4 pt	On foliage	When defoliation reaches 30% before bloom and 20% between bloom and pod fill.
Thrips	*Penncap-M Sevin XLR Plus	2 to 3 pt 2 pt	On foliage	If seedlings are being seriously damaged and some plants are being killed.
Webworms	Sevin XLR Plus	2 to 3 pt	On foliage	When defoliation reaches 30% before bloom and 20% between bloom and pod fill.
Woollybear caterpillars	*Ambush 2E *Asana XL Larvin 3.2F Lorsban 4E *Pounce 3.2EC	3.2 to 6.4 oz 2.9 to 5.8 oz 10 to 16 oz 1 to 2 pt 2 to 4 oz	On foliage	When defoliation reaches 30% before bloom and 20% between bloom and pod fill.

*Use restricted to certified applicators only.
[a]See Table 11 for insecticide restrictions.
[b]The formulation of the product most commonly used in Illinois is listed. If you use another formulation, *read the label* to determine the amount of product per acre.

Table 6. Insecticides for Alfalfa

Spraying blossoming alfalfa can be extremely hazardous to bees. Coordinate with local beekeepers before applying sprays. Beekeepers' names and colony locations may be obtained from your local Extension office.

Insect	Insecticide[a,b,c]	Amount of product per acre[b]	Placement	Timing of application, comments
Alfalfa caterpillar (see Table 2)	*Ambush 2E *Pounce 3.2EC Sevin XLR Plus	3.2 to 12.8 oz 2 to 8 oz 2 pt	On foliage	When damage to foliage is obvious and there are at least 10 nonparasitized larvae per sweep.
Alfalfa weevil (spring treatment for larvae)	*Ambush 2E *Furadan 4F Imidan 50WP Lorsban 4E[d] *Penncap-M *Pounce 3.2EC	12.8 oz 1/2 to 1 pt 2 lb 1 to 2 pt 2 to 3 pt 8 oz	On foliage	When 25 to 40% of tips are being skeletonized and if there are three or more larvae per stem, treat immediately. Do not apply sprays during bloom. Instead, cut and remove the hay. Two treatments may be necessary on first cutting. Control may also be warranted after a cutting when larvae and adults are feeding on more than 50% of the crowns and regrowth is prevented for 3 to 6 days.
Alfalfa weevil adults	*Furadan 4F Imidan 50WP Lorsban 4E[d] *Penncap-M	1 to 2 pt 2 lb 1 to 2 pt 2 to 3 pt	On foliage	Control may be warranted after a cutting when larvae and adults are feeding on more than 50% of the crowns and regrowth is prevented for 3 to 6 days.
Aphids	*Ambush 2E Cygon 400 *Furadan 4F malathion 57%EC *Penncap-M *Pounce 3.2EC	3.2 to 12.8 oz 1/2 to 1 pt 1/2 pt 1-1/2 pt 2 pt 2 to 8 oz	On foliage	When aphids average 100 or more per sweep and lady beetle larvae and adults, parasites, and diseases are not abundant.
Blister beetles	Sevin XLR Plus	1 to 2 pt	On foliage	Although blister beetles rarely cause economic damage to alfalfa, their presence in hay could injure horses if the horses ingest the beetles.
Cutworms	*Ambush 2E Lorsban 4E[d] *Pounce 3.2EC	3.2 to 12.8 oz 1 to 2 pt 2 to 8 oz	On foliage	Control may be warranted when larvae reduce the stand of a new seeding or prevent regrowth after harvest.
Fall armyworm	Lorsban 4E[d]	1 to 2 pt	On foliage	Control may be warranted when larvae reduce the stand of a new seeding, when there are two or more larvae per sweep, or when there are one to two half-grown larvae per square foot.
Grasshoppers	Cygon 400 *Furadan 4F Lorsban 4E[d] *Penncap-M Sevin XLR Plus	1/2 to 1 pt 1/4 to 1/2 pt 1/2 to 1 pt 2 to 3 pt 1 to 3 pt	On foliage	When grasshoppers are small, before damage is severe, and there are 15 to 20 per square yard. The higher rates are suggested for control of adult grasshoppers.

Table 6. Insecticides for Alfalfa (cont.)

Insect	Insecticide[a,b,c]	Amount of product per acre[b]	Placement	Timing of application, comments
Leaf-hoppers	*Ambush 2E	3.2 to 12.8 oz	On foliage	Treatment is justified at these combinations of alfalfa height and leafhopper numbers: Alfalfa height (inches) — Leafhoppers per sweep 0 to 3 — 0.2 3 to 6 — 0.5 6 to 12 — 1.0 12 or taller — 2.0
	Cygon 400	1/2 to 1 pt		
	*Furadan 4F	1 pt		
	Imidan 50WP	2 lb		
	Lorsban 4E[d]	1 to 2 pt		
	malathion 57%EC	1-1/2 to 2 pt		
	*Penncap-M	2 to 3 pt		
	*Pounce 3.2EC	4 to 8 oz		
	Sevin XLR Plus	2 pt		
Plant bugs	*Ambush 2E	6.4 to 12.8 oz	On foliage	When tip damage is obvious and nymphs and adults average three per sweep on alfalfa less than 3 inches tall, or five per sweep on alfalfa taller than 3 inches.
	Cygon 400	1/2 to 1 pt		
	*Furadan 4F	2 pt		
	Lorsban 4E[d]	1 to 2 pt		
	*Penncap-M	2 to 3 pt		
	*Pounce 3.2EC	4 to 8 oz		
	Sevin XLR Plus	2 to 3 pt		
Spittlebug	*Ambush 2E	6.4 to 12.8 oz	On foliage	When spittle masses are found and nymphs average more than one per stem.
	Imidan 50WP	2 lb		
	Lorsban 4E[d]	1 to 2 pt		
	malathion 57%EC	1-1/2 to 2 pt		
	*Penncap-M	2 to 3 pt		
	*Pounce 3.2EC	4 to 8 oz		
Webworms (see Table 2)	*Ambush 2E	3.2 to 12.8 oz	On foliage	Control may be warranted when larvae reduce the stand of a new seeding.
	*Pounce 3.2EC	2 to 8 oz		
	Sevin XLR Plus	2 to 3 pt		

*Use restricted to certified applicators only.
[a]See Table 11 for insecticide restrictions.
[b]Before applying insecticides, be certain to clean all herbicides out of equipment. During bloom, apply very late in day or, if possible, avoid application during bloom.
[c]The formulation of the product most commonly used in Illinois is listed. If you use another formulation, *read the label* to determine the amount of product per acre.
[d]Some phytotoxic symptoms may be observed on young, tender, rapidly growing alfalfa when treated with Lorsban 4E. Alfalfa will outgrow the symptoms and no yield loss should be expected.

Table 7. Insecticides for Grain Sorghum

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Chinch bug	Lorsban 4E[c] Sevin XLR Plus	1 to 2 pt 2 to 4 pt	At plant base	Direct spray towards base of plant. Use only ground equipment and apply 20 to 40 gallons of finished spray per acre.
Corn earworm (see Table 2)	Lannate 90WSP Lorsban 4E Sevin XLR Plus	1/4 to 1/2 lb 1 to 2 pt 2 to 4 pt	Over row	When there is an average of two worms per head.
Corn leaf aphid	Cygon 400 Lorsban 4E[c]	1/2 to 1 pt 1/2 to 1 pt	Over row	Corn leaf aphids rarely cause economic damage unless populations are heavy and drought conditions exist.
Cutworms	Lorsban 4E[c]	1 to 2 pt	Broadcast	When seedling plants are being cut.
Fall armyworm	Lannate 90WSP Lorsban 4E[c]	1/4 to 1/2 lb 1 to 2 pt	Over row	When there is an average of two worms per head. Leaf feeding or whorl damage seldom has an economic effect.
Grasshoppers	Cygon 400 Lorsban 4E[c] Sevin XLR Plus	1 pt 1/2 to 1 pt 1 to 3 pt	Over row	Treatment may be warranted when there are seven or more per square yard. The higher rates are suggested for control of adult grasshoppers.
Greenbug	Cygon 400 Lorsban 4E[c] malathion 57%EC	1/2 to 1 pt 1/2 to 1 pt 1-1/2 pt	Over row	When greenbug damage is sufficient to cause death of more than two normal-sized leaves before the hard-dough stage. *Caution*: Some sorghum varieties are sensitive to organophosphate insecticides.
Sorghum midge	Lorsban 4E[c] Sevin XLR Plus	1/2 pt 1-1/2 to 2 pt	Over row	Apply during bloom when 50% of heads have begun to bloom and there are one or more midge adults (flies) per head.
Webworms	Lorsban 4E[c] Sevin XLR Plus	1 pt 2 to 4 pt	Over row	When five or more larvae per head are found.
White grubs	*Counter 15G *Counter 20CR	8 oz per 1,000 ft row 6 oz per 1,000 ft row	Band Band	At planting, if crop history and previous crop losses can be directly linked to a repeated history of grub damage.
Wireworms	*Counter 15G *Counter 20CR *Furadan 15G (see page 20)	8 oz per 1,000 ft row 6 oz per 1,000 ft row 8 oz per 1,000 ft row	Band Band Furrow	At planting, if crop history and/or bait stations indicate a potential for wireworm damage.
	lindane	See label	On seed	Use seed treatment formulations. See label for proper disposal of treated seeds.

Table 7. Insecticides for Grain Sorghum (cont.)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Yellow sugar-cane aphid	Cygon 400 Lorsban 4E[c]	1/2 to 1 pt 1/2 to 1 pt	Over row	Sprays should be applied at first sign of damage to seedling sorghum; 5 to 10 aphids per leaf.

*Use restricted to certified applicators only.
[a]See Table 11 for insecticide restrictions.
[b]The formulation of the product most commonly used in Illinois is listed. If you use another formulation, *read the label* to determine the amount of product per acre.
[c]To minimize chemical injury, do not apply Lorsban 4E to drought-stressed grain sorghum within 3 days following irrigation or rain except where the product is applied in irrigation water.

Table 8. Insecticides for Small Grains (Barley, Oats, Rye, Wheat)

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Armyworm (see Table 2)	*Penncap-M Sevin XLR Plus	2 to 3 pt 2 to 3 pt	On foliage	When there are six or more nonparasitized armyworms (3/4 to 1-1/4 inch long) per linear foot of row and before extensive head cutting occurs. Do not use Penncap-M on rye. Sevin is labeled for use only in wheat.
Cereal leaf beetle	*Furadan 4F malathion 57%EC Sevin XLR Plus	1/2 pt 1 to 1-1/2 pt 2 pt	On foliage	When there are one or more small larvae per stem or flag leaf. Apply Furadan before heads emerge from the boot. Do not use Furadan on rye. Sevin is labeled for use only in wheat.
Grass-hoppers	Cygon 400 *Furadan 4F malathion 57%EC *Penncap-M Sevin XLR Plus	3/4 pt 1/4 to 1/2 pt 1-1/2 pt 2 to 3 pt 1 to 3 pt	On foliage	During fall when damage is apparent, treat field borders and noncrop areas to stop migration. The higher rates are suggested for control of adult grasshoppers. Do not apply Penncap-M to rye. Do not use Furadan on rye. Apply Furadan before heads emerge from the boot. Sevin and Cygon are labeled for use only in wheat.
Greenbug, English grain aphid, oat bird-cherry aphid	Cygon 400 malathion 57%EC *Penncap-M	1/2 to 3/4 pt 1-1/2 pt 2 to 3 pt	On foliage	Aphids damage plants indirectly by transmitting disease. Once yellowing is noticeable, it is usually too late to treat. Use Cygon on wheat only. Do not apply Penncap-M to rye.

*Use restricted to certified applicators only.
[a]See Table 11 for insecticide restrictions.
[b]The formulation of the product most commonly used in Illinois is listed. If you use another formulation, *read the label* to determine the amount of product per acre.

Table 9. Insecticides for Grass Pasture

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Armyworm	malathion 57%EC *Penncap-M Sevin XLR Plus	2 pt 2 to 3 pt 2 to 3 pt	On foliage	Do not apply when weeds are blooming.
Grass-hoppers	malathion 57%EC *Penncap-M Sevin XLR Plus	1-1/2 to 2 pt 2 to 3 pt 1 to 3 pt	On foliage	When there are 15 to 20 per square yard. The higher rates are suggested for control of adult grasshoppers. Do not apply when weeds are blooming.

*Use restricted to certified applicators only.
[a]See Table 11 for insecticide restrictions.
[b]The formulation of the product most commonly used in Illinois is listed. If you use another formulation, *read the label* to determine the amount of product per acre.

Table 10. Insecticides for Noncrop Areas

To avoid injury to bees, do not apply sprays to noncrop areas if weeds are blooming.

Insect	Insecticide[a,b]	Amount of product per acre[b]	Placement	Timing of application, comments
Grass-hoppers	*Asana XL *Penncap-M Sevin XLR Plus	2.9 to 5.8 oz 2 to 3 pt 1 to 3 pt	On foliage	When grasshopper nymphs average 15 to 20 per square yard along roadsides and fencerows. Apply treatments while hoppers are small and before they migrate into row crops. The higher rates are suggested for control of adult grasshoppers. Do not spray areas adjacent to water or where runoff is likely to occur.

*Use restricted to certified applicators only.
[a]See Table 11 for insecticide restrictions.
[b]The formulation of the product most commonly used in Illinois is listed. If you use another formulation, *read the label* to determine the amount of product per acre.

Table 11. Harvest Restrictions

Limitations in days between application of the insecticide and harvest of crop and restrictions on use of insecticides for field crop insect control. These are only guidelines. Read the label for more detailed information. Blanks denote that the product may not be labeled or suggested for that specific use in Illinois.

	Field corn		Forage crops			
Insecticide	Grain	Ensilage	Sorghum	Alfalfa	Clover	Pasture
*Ambush 2E, 25W (permethrin)[a,b]	A	A	...	B	...	...
*Asana XL (esfenvalerate)	21,C	21,C	...	...	...	...
*Counter 15G, 20CR (terbufos)	D	30,D	E	...	...	...
Cygon 400 (dimethoate)[b]	14,F	14,F	28,F	10,G	...	...
*Dyfonate II 20G, 15G (fonofos)[a,b]	45	30	...	...	...	...
*Force 1.5G (tefluthrin)	H	H	...	...	...	...
*Furadan 15G, 4F (carbofuran)[a,b]	30,I,J	30,I,J	75	K	...	...
Imidan 50WP (phosmet)	14	14	...	7,G	...	...
Lannate 90WSP (methomyl)[a,b]	0	3	14	...	...	...
Lorsban 15G, 4E (chlorpyrifos)	35,L	14,L	M	N	...	...
malathion 57%EC	5	5	7	0	0	0
*Penncap-M (microencapsulated methyl parathion)[a,b]	12	12	...	15	...	15
*Pounce 3.2EC, 25WP, 1.5G (permethrin)[a,b]	P	P	...	B	...	...
Sevin XLR Plus (carbaryl)	0	0	21	7,Q	0	R
Thimet 20G, 15G (phorate)	30,S	30,S	...	...	...	...

	Barley	Oats	Rye	Wheat	Soybeans
*Ambush 2E, 25W (permethrin)[a,b]	...	...	...	...	60,T
*Asana XL (esfenvalerate)					
Cygon 400 (dimethoate)[b]	...	...	...	...	21,U
*Furadan 15G, 4F (carbofuran)[a,b]	...	...	...	35,V	21,W
Larvin 3.2F (thiodicarb)	X	X	...	X	21,Y
Lorsban 15G, 4E (chlorpyrifos)	...	...	...	...	28,Z
malathion 57%EC	...	...	...	...	28,AA
Orthene 75S (acephate)	7	7	7	7	...
*Penncap-M (microencapsulated	...	...	...	...	14,Z
methyl parathion)[a,b]	15	15	...	15	20,BB
*Pounce 3.2EC, 25WP (permethrin)[a,b]	...	...	...	...	60,T
Sevin XLR Plus (carbaryl)	...	...	...	21	0

Read the label for more detailed information

A. Apply prior to the brown silk stage. For aerial application, do not apply within 100 yards of aquatic habitats. For ground application, do not apply within 20 yards of aquatic habitats.

B. Do not apply more than 0.2 pound active ingredient per cutting. When rates of 0.1 pound active ingredient per acre or less are used, application may be made on day of harvest. When rates greater than 0.1 pound active ingredient per acre are used, do not apply within 14 days of harvest. For aerial application, do not apply within 100

yards of aquatic habitats. For ground application, do not apply within 20 yards of aquatic habitats.
C. Do not exceed 0.25 pound of active ingredient of Asana per acre per season for field and seed corn. Do not exceed 0.5 pound of active ingredient per acre per season for popcorn.
D. Only one at planting, postemergence incorporated, or cultivation time treatment of Counter may be used.
E. Only one application of Counter per year may be used.
F. Make no more than three applications of Cygon per year. Do not apply to corn during the pollen-shed period if bees are actively foraging in the treated area. Do not apply to sorghum after heading.
G. Apply only once per cutting. Do not apply if the crop or weeds in the treatment areas are in bloom.
H. Do not rotate to crops other than soybeans or corn. Soybeans may be planted 12 months after application of Force 1.5G. Do not apply this product within 20 yards of water (ponds, streams, or lakes).
I. Do not make a foliar application if Furadan 15G was applied at more than 8 ounces per 1,000 linear feet of row (6.7 pounds per acre with 40-inch row spacing) at planting. Do not make more than two foliar applications of Furadan 15G per season.
J. Do not make more than two applications of Furadan 4F per season at the 1-1/2 to 2-pint use rate. Do not make more than four applications per season at the 1-pint use rate. Do not apply Furadan 4F on seed corn less than 14 days prior to detasseling or rogueing.
K. Do not apply more than twice per season. Do not apply more than once per cutting. Do not use more than 1 pint per acre in the second application. Apply only to fields planted to pure stands of alfalfa. Do not move bees to alfalfa fields within 7 days of application. Do not cut or graze within 7 days if 1/2 pint of Furadan 4F is applied per acre, 14 days if 1 pint is applied per acre, 28 days if 2 pints are applied per acre.
L. For soil insect control, do not exceed the equivalent of 16 ounces of Lorsban 15G per 1,000 feet of row or 13.5 pounds of Lorsban 15G per acre per crop season. For foliar insect control, do not exceed the equivalent of 16 ounces of Lorsban 15G per 1,000 feet of row or 13 pounds of Lorsban 15G per acre per crop season. Do not apply more than a total of 15 pints of Lorsban 4E per acre per season. Do not allow livestock to graze in treated areas nor harvest treated corn silage as feed for meat or dairy animals within 14 days after last treatment. Do not feed treated corn fodder to meat or dairy animals within 35 days after last treatment.
M. The treated crop is not to be used for grain, forage, fodder, hay, or silage within 30 days after application of 1 pint of Lorsban 4E per acre or within 60 days after application of rates above 1 pint per acre. Do not treat sweet varieties of sorghum. Do not apply more than 3 pints of Lorsban 4E per acre per season. Do not make more than one application of Lorsban 15G per season.
N. Do not apply more than once per cutting. Do not cut or graze treated alfalfa within 7 days after application of 1/2 pint of Lorsban 4E per acre, within 14 days after application of 1 pint per acre, or within 21 days after application of rates above 1 pint per acre. Do not make more than 4 applications per year.
P. Apply Pounce 3.2EC prior to the brown silk stage. For aerial application, do not apply within 100 yards of aquatic habitats. For ground application, do not apply within 20 yards of aquatic habitats. Do not apply more than 0.4 pound active ingredient of Pounce 1.5G per acre after the brown silk stage. Do not exceed a total of 1.0 pound active ingredient per acre per season.
Q. Apply Sevin only once per cutting for alfalfa at 1-1/2 quarts.
R. Do not allow foraging or cut for hay within 14 days of last application of Sevin by ground. Aerially treated pastures may be grazed or cut for hay on the day of treatment. Apply a maximum of two applications per year. Allow at least 14 days between applications.
S. Do not apply more than twice per season or make any applications of Thimet after cultivation treatment.
T. Do not graze or feed soybean forage or hay. Do not apply more than 0.4 pounds active ingredient per acre per season. For aerial application, do not apply within 100 yards of aquatic habitats. For ground application, do not apply within 20 yards of aquatic habitats.
U. Do not feed or graze livestock on treated plants. Do not exceed 0.2 pound of active ingredient per acre per season.
V. Do not apply within 14 days of grazing immature plant. Do not make more than two applications per season.
W. Do not feed or graze within 5 days of last application.
X. Apply before heads emerge from boot. Do not make more than two applications per season. Do not feed treated forage to livestock.
Y. Do not use Furadan 4F as a foliar application if Furadan 10G, Furadan 15G, or Furadan 4F was applied to soybeans at planting time. Do not make more than two foliar applications per season. Do not graze or feed foliar-treated forage to livestock or cut for silage or hay.
Z. Do not graze or feed treated crop to livestock.
AA. Do not apply more than 6 pints of Lorsban 4E per acre or 3 pounds of chlorpyrifos (active ingredient) per acre per season. Do not apply last treatment within 28 days before harvest or apply last two treatments closer than 14 days apart. Do not allow livestock to graze in treated areas or otherwise feed treated soybean forage, hay, and straw to meat or dairy animals. On determinate soybeans do not apply more than one application after pod set.
BB. Do not make more than two applications per season.

*Use restricted to certified applicators only.
[a]Workers should be warned in advance of treatments. Workers may not enter fields treated with the insecticides without wearing protective clothing for the intervals indicated. They may not enter a field treated with other insecticides without protective clothing until the spray has dried or the dust has settled. Protective clothing includes a hat, long-sleeved shirt, full-length pants, and shoes and socks.
[b]Sprays to be applied only by experienced operators wearing proper protective clothing.

Table 12. Relative Toxicities of Commonly Used Agricultural Insecticides

Always read the label before applying insecticides.

Trade name	Chemical class[b]	Chemical name	Toxicity to mammals[a] Acute oral	Toxicity to mammals[a] Acute dermal	Toxicity to Birds	Toxicity to Fish	Toxicity to Bees
*Ambush	P	permethrin	Low	Low	Low	Very high	High
*Asana	P	esfenvalerate	Moderate	Low	Low	Very high	High
*Counter	OP	terbufos	High	High	High	Very high	...
Cygon	OP	dimethoate	Moderate	Moderate	Moderate	Very low	High
Diazinon	OP	diazinon	Moderate	Moderate	High	High	High
Dipel, (also Biobit, Full-Bac, Javelin)	...	*Bacillus thuringiensis*	Very low	Very low	Very low	Very low	Low
*Dyfonate	OP	fonofos	High	High	High	Very high	...
*Force	P	tefluthrin	Low	Low	Low	Very high	...
*Furadan	C	carbofuran	High	Moderate	High	Moderate	High
Imidan	OP	phosmet	Moderate	Low	Moderate	Moderate	High
Lannate	C	methomyl	High	Moderate	Low	Moderate	High
Larvin	C	thiodicarb	Moderate	Low	Low	Moderate	Moderate
Lorsban	OP	chlorpyrifos	Moderate	Moderate	Moderate	Very high	High
Malathion	OP	malathion	Low	Low	Low	Moderate	High
Orthene	OP	acephate	Moderate	Moderate	Moderate	Low	High
*Penncap-M	OP	microencapsulated methyl parathion	Moderate	Low	Moderate	Very low	High
*Pounce	P	permethrin	Low	Low	Low	Very high	High
Sevin	C	carbaryl	Low	Low	Very low	Very low	High
*Thimet	OP	phorate	High	High	Moderate	Very high	...

*Use restricted to certified applicators only.
[a]Relative toxicities based on acute oral and acute dermal LD_{50} values of technical insecticide. Toxicities of formulated materials vary.
[b]OP = organophosphate, P = pyrethroid, C = carbamate.

Table 13. Worker Reentry Periods in Fields Where Insecticides Have Been Applied

Protective clothing means, at least, a hat or other suitable head covering, a long-sleeved shirt and long-legged trousers or a coverall type of garment, shoes, and socks.

Insecticide	Reentry statement on label
Ambush 2E	Do not enter treated areas without protective clothing until sprays have dried.
Asana XL	Do not enter treated areas without protective clothing until sprays have dried.
Biobit FC	Do not enter treated areas without protective clothing until sprays have dried.
Counter 15G, 20CR	Do not enter treated areas without protective clothing until treatments have been completed.
Cygon 400	Do not enter treated areas without protective clothing until sprays have dried.
Dyfonate II 20G	With foliar applications for corn, do not allow reentry into treated fields within 10 days of application unless appropriate protective clothing is worn.
Force 1.5G	None specified on label.
Furadan 4F, 15G	If prolonged intimate contact with corn and sorghum will result, do not reenter treated field within 14 days without proper protective clothing. For all other situations, do not reenter field less than 24 hours following application. Do not apply on seed corn less than 14 days prior to detasseling or rogueing.
Imidan 50W	Do not enter treated areas without appropriate protective clothing within 24 hours of application.
Lannate 90WSP	Do not enter treated areas without appropriate protective clothing for 2 days for corn and within 1 day for sorghum.
Larvin 3.2F	Do not enter treated areas without appropriate protective clothing until sprays have dried.
Lorsban 4E	Do not allow reentry into treated areas within 24 hours, unless protective clothing is worn.
Lorsban 15G	None specified on label.
malathion 57%EC	Do not enter treated areas without appropriate protective clothing until sprays have dried.
Orthene 75SP	Reentry into treated areas is prohibited for 24 hours after the end of application unless protective clothing is worn.
Penncap-M	Reentry into treated fields is prohibited for 48 hours after application.
Pounce 1.5G	None specified on label.
Pounce 3.2EC	Do not enter field without appropriate protective clothing until sprays have dried.
Sevin XLR Plus	Do not enter treated areas without protective clothing until sprays have dried.
Thimet 20G	After dusts have settled, do not enter or allow entry into the treated area until the 48-hour reentry interval has expired.

2 Alternatives in Insect Management: Field and Forage Crops

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Contents

Field Crops, Insects, and Insecticides in Illinois 42
Illinois Field Crops 42
Major Field Crop Pests 42
Insecticide Use 42

Production Practices and Insect Pest Management 42
Crop Rotation 42
Resistant Varieties 47
Altering Planting or Harvesting Dates 53
Trap Crops 56
Reduced Tillage 57
Cover Crops 57
Intercropping 58

Controlling Pest Infestations 59
Monitoring Pest Populations 59
Thresholds for Control 59
Selecting Alternative and Conventional Control Methods 62

Synthetic insecticides play an essential role in agriculture today. Yet regulatory actions, concerns about the environment and human health, and the high costs of some insecticides are encouraging researchers and farmers to seek alternative methods of insect control. To meet the needs of agriculture and society, those alternatives must be practical, effective, and economical; they also should provide environmental and human health advantages in comparison with currently used insecticides.

This chapter examines the pest management impacts of crop production practices specifically intended to provide pest management alternatives or to reduce erosion, enhance fertility, or provide other benefits. Such practices include rotating crops, planting resistant varieties, manipulating planting or harvesting dates, and using trap crops. The pest management consequences of reduced tillage, cover crops, and intercropping are also discussed. We include pest-specific recommendations, references on scouting and economic thresholds, and suggestions for choosing the most appropriate control practices when pest outbreaks occur.

The efficacy of many of the practices mentioned here have been recognized for many years; however, the low cost of the highly effective synthetic insecticides first produced in the 1940s and 1950s allowed the development of crop production systems that are less reliant on agronomic practices intended to reduce pest problems. Changing attitudes about the use of pesticides and increased knowledge of the ecology of pest management now provide a new context for judging these "old" alternatives.

Chapter 1 of this *Handbook,* "Insect Pest Management for Field and Forage Crops," contains guidelines for monitoring insect infestations, presents thresholds, and lists insecticides registered for specific crop-pest combinations. Another useful reference for the management of field crop pests is the *Field Crop Scouting Manual* (Curran et al. 1990).

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

Field Crops, Insects, and Insecticides in Illinois

Evaluating alternatives for the management of field crop pests requires an understanding of current problems and practices. A review of information on major crops, major insect pests, and insecticide use provides a starting point for that understanding.

Illinois Field Crops

In 1990, field crops were grown on about 23 million acres of Illinois cropland (Pike et al. 1991). Most of that acreage produced corn and soybeans (46 percent and 39 percent of the total, respectively); smaller but substantial portions of the state's crop acreage were used to raise wheat (8 percent) and hay (3 percent). Sorghum, oats, and pasture together accounted for another 4 percent of the state's field crop acreage. In 1990, approximately 3 million acres of Illinois cropland were held out of production in "set-aside" acreage, a part of the federal farm program intended mainly to prevent overproduction of certain commodities. This publication centers on the four major field crops in Illinois: corn, soybeans, wheat, and alfalfa.

Major Field Crop Pests

Many insects infest field crops in Illinois. Although several species cause significant damage in sporadic outbreaks, only a few species consistently cause enough damage to be considered major pests. Designing management programs for these pests requires at least a general knowledge of their life cycles and the damage they cause. Table 1 summarizes that information. Although this chapter concentrates on the major pests listed in Table 1, information on less important pests is included where appropriate.

Insecticide Use

Existing patterns of insecticide use must be understood before alternatives can be considered. Table 2, adapted from *Pesticide Use in Illinois: Results of a 1990 Survey of Major Crops* (Pike et al. 1991), provides data useful for developing that understanding. Important observations from Table 2 include the following:

- Approximately 34 percent of all corn acreage was treated with a soil insecticide in 1990. Most of these treatments (on 25 percent of the total corn acreage) were used to control corn rootworms.

- Postemergence insecticides were used on approximately 5 percent of all corn acreage in 1990. This level of postemergence insecticide application is typical, although in some years outbreaks of black cutworms or European corn borers warrant more widespread treatments.

- Although 40 percent of the state's 9 million acres of soybeans received an insecticide (miticide) application to control spider mites in 1988, less than 1 percent of Illinois' soybeans were treated with a postemergence insecticide in 1990. This extremely low frequency of insecticide treatment is typical for soybeans in Illinois except in years when drought triggers mite outbreaks.

- Insecticide use on hay (primarily alfalfa) in 1990 was also representative of average application trends, as insecticides commonly are used on 10 to 35 percent of the Illinois alfalfa crop for alfalfa weevil control and 5 to 15 percent of the crop for leafhopper control. Alfalfa weevil infestations are typically greatest in the southwestern portion of the state.

Table 2 clearly indicates that the majority of the state's field crop acreage is not treated with any insecticide. (The situation differs in fruits and vegetables where cosmetic standards dictate greater use of insecticides and fungicides. In addition, nearly 100 percent of the state's corn and soybean acreage is treated with one or more herbicides each year.) Although insecticides are not used in all fields, opportunities to reduce insecticide use do exist.

Production Practices and Insect Pest Management

Farming practices ("cultural practices") influence pest populations. Crop rotation, planting different crops in a field in successive years instead of planting the same crop every year, disrupts the life cycles of some major insect pests; it also contributes to weed control. Other cultural practices that are important in the management of insect pests include planting resistant varieties, following planting or harvesting schedules that avoid peak periods of pest attack, and using trap crops. Tillage practices, cover crops, and intercropping also produce important impacts on pest populations.

Crop Rotation

Benefits of Crop Rotation

Crop rotations minimize problems with weeds, diseases, nematodes, and insects that thrive only in certain crops. Crop rotations aid in weed control because they allow a farmer to use different cultivation practices and different herbicides so that weeds that are difficult to control in one crop can be controlled by

Table 1. Major Field Crop Pests in Illinois

Crop and pest	Damaging stage	Type of damage	Generations per year	Overwintering stage
Corn				
Northern and western corn rootworms	Larva	Feeds on corn roots, causing physiological stress, lodging, and reduced yields.	1	Egg, in soil
	Adult	Feeds on corn silks, causing reduced pollination and poorly filled ears.		
Wireworms	Larva	Feeds on germinating seeds or seedling stems below the soil surface; may kill plants, reducing stands. Infestations often scattered, spotty.	< 1	Larva or pupa, in soil
White grubs	Larva	Feeds on roots of seedlings, causing them to wilt or die, reducing stands. Infestations often scattered, spotty.	< 1	Larva, in soil
Black cutworm	Larva	Feeds on foliage or cuts off young seedlings at soil level.	3	Migrates into Illinois from south each spring
European corn borer	Larva	First generation feeds on foliage and bores into stem of whorl-stage plants, causing physiological stress. Second-generation larva tunnels into ears, ear shanks, and stems near the tassel, causing breakage, lodging, and ear drop. Tunneling in stalk also reduces yield.	2 to 3	Mature larva, in corn stubble
Corn leaf aphid	Nymph and adult	Can build to high numbers in the whorl at tasseling. Aphids suck plant sap, causing wilting. Honeydew can lead to sooty molds, poor pollination, and undersized kernels. Greatest damage in dry years.	Many	Migrates into Illinois from south each summer
Soybeans				
Bean leaf beetle	Adult	Feeds on cotyledons and stems of seedlings, sometimes reducing stands. Later generations feed on foliage and pods. Pod feeding can contribute to seed diseases.	2	Adult, in leaf litter in wooded or protected sites
Grasshoppers	Nymph and adult	Feed on all aboveground plant parts. Usually move into fields from roadsides and noncrop areas late in the season.	1	Egg (in "pods"), in soil
Twospotted spider mite	Nymph and adult	Suck plant cell contents, reducing photosynthetic capacity. Yellowing and browning of leaves is followed by wilting. Seldom damaging except in unusually dry seasons.	Many	Females, in vegetation (roadsides, waterways, and noncrop areas)

Table 1. Major Field Crop Pests in Illinois (cont.)

Crop and pest	Damaging stage	Type of damage	Generations per year	Overwintering stage
Wheat				
Armyworm	Larva	Consumes plant foliage and sometimes feeds on ripening heads. Occasional pest that infrequently causes economically important damage.	2 to 3	Mature larvae, in soil
Hessian fly	Larva	Feeds between leaf sheath and stem. May kill the plant by destroying the growing tip; interferes with tillering; causes lodging, stunting, reduced weight, or winter kill; or leads to fungal infections.	2	Mature larva, in "flax-seed" puparium on the wheat stem
Alfalfa				
Alfalfa weevil	Larva and adult	Larva feeds on the new buds and young foliage; adult skeletonizes foliage and sometimes feeds on regrowth after the first cutting. Extensive damage reduces yield and quality of hay.	1	Egg or adult in alfalfa stems and crowns
Potato leafhopper	Nymph and adult	Suck plant sap causing V-shaped yellowing of leaf tips and general wilting. Chemical changes in response to feeding cause reduced protein and elevated sugar content, stunting, and overall reduced yield.	3 to 4	Migrates into Illinois from south each summer

Table 2. Insecticide Use on Illinois Corn, Soybeans, and Alfalfa in 1990

Crop	Acres grown	Target pest	Acres treated	Approximate percent of crop treated
Soil Insecticides				
Corn	10,589,000	Corn rootworms	2,696,000	25%
		Wireworms	190,000	2%
		Cutworms	703,000	7%
			3,589,000	34%
Postemergence Insecticides				
Corn	10,589,000	Cutworms	86,700	0.8%
		First-generation European corn borers	361,900	3.4%
		Second-generation European corn borers	22,700	0.2%
		Corn rootworm beetles	3,400	<0.1%
		Other pests	7,600	<0.1%
			482,300	4.6%
Soybeans	9,132,000	Bean leaf beetle or grasshoppers	26,400	0.2%
		Spider mites	6,200	<0.1%
			32,600	0.3%
Hay	617,000	Alfalfa weevil	97,000	15.7%
		Potato leafhopper	60,000	9.7%
			157,000	25.4%

SOURCE: Pike et al. (1991); data interpreted from Table 21.

different methods in another. Rotations are especially important for managing crop diseases because many pathogens decline in density during the years when nonhost crops are grown. Certain rotations, especially those including legumes, build or maintain soil structure or fertility.

Although rotating crops provides many benefits, it does not affect all insects equally. Insects most susceptible to control by crop rotation are soil-dwelling pests that are crop-specific and relatively nonmobile (at least in the larval stage that causes the most damage). Of those, the species most affected by rotation overwinter in the soil as eggs or partially grown larvae. Rotating to a different crop removes the pest's food source, and the pest dies of starvation when it becomes active in the spring.

Crop rotation does not control insects that migrate into Illinois from the south each spring (for example, black cutworm, armyworm, and potato leafhopper). Rotation is also ineffective against highly mobile insects that overwinter in Illinois as adults, pupae, or fully mature larvae that pupate and emerge as mobile adults in the spring (European corn borer and bean leaf beetle, for example). Adults of these insects deposit their eggs in suitable crops in the spring and early summer, and the subsequent generation damages the crop during the same season.

While crop rotation does not control most of the insect pests of Illinois field crops, it does control two extremely important pests, the northern and western corn rootworms. As larvae, these insects feed only on the roots of corn. The eggs are laid in soil at the base of corn plants in late summer, and they hatch the following spring (see Figure 1). If corn is present again in the same field, the larvae feed on and may cause serious damage to the root system. If another crop such as soybeans is present, the larvae die of starvation soon after hatching because they are unable to disperse from the field to locate a corn crop.

Patterns of insecticide use (from Pike et al. 1991) illustrate the importance of crop rotation in managing corn rootworms. In 1990, 26 percent of the Illinois corn crop was grown in fields that had produced corn in 1989 (corn after corn); 67 percent was corn after soybeans; and the remaining 7 percent was corn after wheat, alfalfa, or other crops. Of the corn-after-corn acreage, 88 percent (over 2 million acres) was treated with a soil insecticide at planting, primarily for corn rootworm control. Only 13 percent of the corn after soybeans and 49 percent of the corn after other crops were treated with a soil insecticide at planting, primarily to control cutworms, wireworms, or white grubs.

Any rotation that avoids producing corn in the same field in successive years prevents economically important damage from corn rootworms in Illinois. This benefit remains true even though researchers have observed that a portion of the eggs of the northern corn rootworm can remain dormant for more than one winter. When this phenomenon (called extended diapause) occurs, larvae hatch 1 or 2 years later than normal, sometimes in fields where corn has again been planted following other rotation crops. Although northern corn rootworms can cause some damage to corn when extended diapause occurs, only very rarely have infestations caused economic damage to corn planted in rotation with any other crop in Illinois. Crop rotation remains effective for corn rootworm control in Illinois despite the infrequent occurrence of extended diapause in the northern corn rootworm.

Other Illinois insects managed in part by rotation are corn billbugs in corn, grape colaspis in soybeans, and the Hessian fly in wheat. However, because billbugs and grape colaspis seldom occur at damaging levels, and because rotations offer only limited control of the Hessian fly, these pests are rarely considered in crop rotation plans.

Problems Associated with Crop Rotations

Not all crop rotations reduce the densities of important pests. Some species of wireworms and white grubs are favored by rotations that include grasses, perennial legumes, or set-aside acreage, especially if weed growth is uncontrolled. These pests often cause economic damage by feeding on the seedlings and roots of corn planted in rotation after grass pastures and set-aside acreage.

In summer months, adult wireworms and white grubs (beetles shown in Figures 2 and 3) deposit their eggs mostly in grasses, perennial legumes, or uncultivated areas. Larvae of common species feed in the soil for three to five years, a period during which several crops may be grown in a single field. Wire-

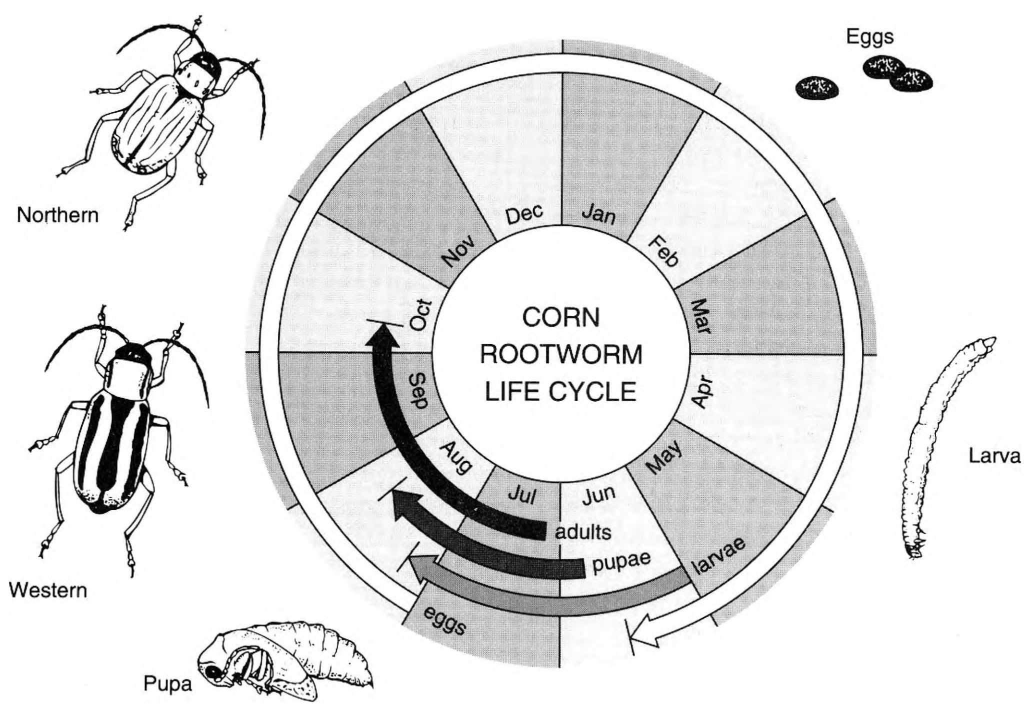

Figure 1. Life cycle of western and northern corn rootworms. Eggs deposited in cornfields in August and September overwinter and hatch in late May and early June. Larvae feed on corn roots in June and July before pupating. Adult beetles are active in late July, August, and September. (Illustration adapted from Publ. E-201, Purdue University, West Lafayette, Indiana.)

worm larvae feed below the soil surface on seeds and on the underground stems and roots of many plants, including corn. White grubs also feed on the roots and underground stems of a range of plants. Despite their general feeding habits, wireworms and white grubs rarely cause economic damage to crops other than corn in Illinois.

Crop rotations that alternate corn and soybeans generally experience the fewest problems with wireworms and white grubs. These pests are more common in corn planted in more complex rotations that include small grains, pasture grasses, and legumes, at least in part because these crops are more attractive to egg-laying beetles. Consequently, scouting for wireworms and white grubs is especially important where corn is to be planted in fields formerly used for pastures, legumes, or set-aside acreage.

Because crop rotations provide benefits other than insect control (building soil structure and fertility and contributing to weed and disease management, for example), producers may elect to design a generally favorable crop rotation and then deal with subsequent insect problems as effectively as possible. The probable impacts of common Illinois crop rotations on pest insects are presented in Table 3.

Constraints on Rotations

Although crop rotation usually provides substantial benefits, some rotations are not economically or ecologically desirable in all areas. The rotations that work at specific locations depend on soil type, land contours, climate (length of growing season, severity of winters, etc.), the nature of farm operations, and participation in federally sponsored farm programs. For example, most of the continuous corn in Illinois is grown in the northwest portion of the state where rolling lands are highly erodible. Rotating corn with soybeans is undesirable there because soybean stubble does not prevent the erosion of soil by running water as effectively as corn stubble. Although the use of winter cover crops might help to hold the soil after soybean harvest, establishing a cover crop before winter is not always possible in this region. In addition, many farmers in northwestern Illinois raise hogs or cattle and may require supplies of corn (for feed) that can be met most economically by raising corn on the majority of their acreage. While planting corn after corn favors certain insects and crop diseases, it may be the most economical practice (at least in the short term) on these farms, despite the fact that fertilizer and insecticide inputs are usually relatively high.

Federally sponsored farm programs also interfere with crop rotations in some instances. These programs attempt to optimize production and marketing by subsidizing the production of certain commodities and by paying farmers to set aside some acreage. Because farm program benefits vary according to the acreage "base" that a farmer has devoted to corn production (or the production of certain other crops), planting at least some corn after corn without rotation has led to an increase in farm program payments in some cases. Because federal farm programs have become extremely complex, their influence on crop rotations and insect management represents only a minor portion of their overall impacts on farming. Nonetheless, any changes in farm programs that encourage or allow optimum use of crop rotations for pest management should be considered as important improvements.

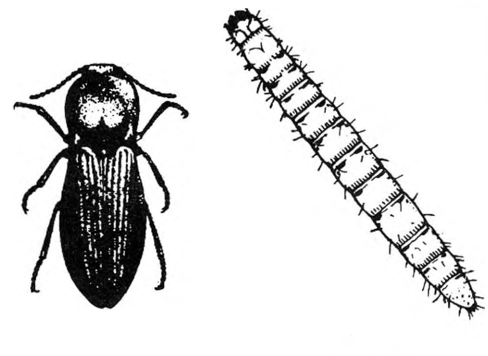

Figure 2. Wireworm adult and larva. Adult beetles deposit eggs in grasses, perennial legumes, and noncrop areas in the summer. Larvae feed on underground parts of plants including corn seeds and seedlings. Larvae feed for 3 to 5 years before maturing to the adult stage. (Illustration adapted from Extension Circular E-188, North Dakota State University, Fargo.)

Resistant Varieties

Through evolution, many plants have developed defenses against diseases, insects, and larger plant-eating animals. They may produce repellent or toxic chemicals; possess thorns, hairs, or tough tissues that act as physical barriers; or have growth habits that protect them from attack or help them to recover. These traits are all determined genetically.

During the process of breeding crops for high yield and food quality, some protective or defensive traits present in wild or more primitive species or strains have been enhanced; others have been lost. When traits that provide insect resistance have been the objects of breeding programs, specific resistant varieties have resulted (see Tables 4 and 5 and the section on European corn borer in Chapter 1, "Insect Pest

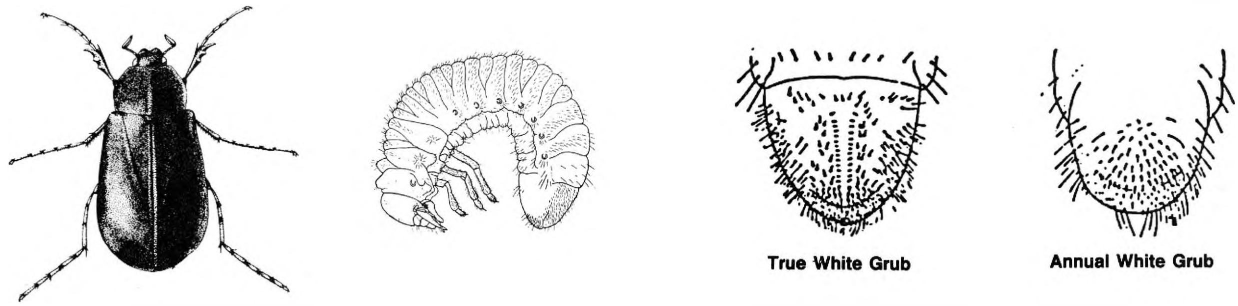

Figure 3. White grub adult and larva. The last abdominal segment of perennial white grubs ("true" white grubs) bears bristles arranged in a zipperlike pattern; the corresponding bristles on annual white grubs are not arranged in such a pattern. Although annual white grubs cause little or no damage in field crops, perennial white grubs can cause economic losses. (Illustrations adapted from Bulletin 773, Agricultural Experiment Station, University of Illinois at Urbana-Champaign and from MP 517, University of Missouri, Columbia.)

Management for Field and Forage Crops"). In other instances, overall plant vigor or at least some level of resistance to common pests allows commercial varieties to withstand moderate infestations even though specific varieties have not been marketed for their resistance to specific pests. Examples of such tolerance to pest attack include corn root regrowth following rootworm damage, the "standability" and yield of current corn varieties when infested by European corn borer, and the ability of soybean varieties to yield well despite substantial defoliation.

Conversely, defensive traits can be "bred out" as a result of breeders' efforts to select otherwise superior varieties. The loss of defensive traits can occur inadvertently when insecticides are used to prevent insect damage during selective breeding programs. Where insecticides are used during variety development, the selection process cannot identify improvements or losses of insect resistance. The unintentional selection of susceptible varieties can result in part from plants using limited resources in their growth and reproduction; energy and nutrients used for defense may reduce the resources available for yield. In contrast, varieties that produce higher yields may do so by reducing the resources allocated to certain defense mechanisms.

Variety development programs may even reduce resistance mechanisms intentionally. Although a current example of crop improvement involves an endophytic fungus (a fungus that lives within a plant) instead of a crop-produced compound, it illustrates the underlying issue. Tall fescue, a widely used pasture grass, is commonly infected by a seed-borne fungus (an endophyte) that produces antibiotic compounds that interfere with the development of insects, thereby providing at least some degree of insect resistance to the infected fescue. Unfortunately, these fungus-produced chemicals are also toxic to cattle and other mammals. Cattle that feed on endophyte-infected fescue often lose weight or gain weight at rates substantially lower than normal. Severe injuries and death can occur when animals consume large amounts of the fungus in infected grass. As a result, cattle producers are attempting to establish endophyte-free stands of fescue to improve cattle performance. (Simultaneously, the grass seed industry is marketing endophyte-infected seed to provide insect resistance in home lawns.) The key concern in this and similar situations is that resistance mechanisms that depend on the production of chemical substances toxic to invertebrate and vertebrate animals alike limit the feed or food value of the crop plant. Selecting varieties less resistant to pests but more nutritious to livestock and humans can involve targeting the same plant chemical.

Types of Resistance

Crop resistance to insects can be characterized in several ways. It may be **physical**, resulting from the toughness of tissues, the thickness of stems, roots, or other structures, or the kinds and degree of pubescence (hairiness); **chemical**, resulting from the production of any of a wide array of compounds that repel, deter, weaken, or kill insects that attempt to feed; or **phenological**, resulting from the timing of crop development so that the presence of the susceptible stage of the plant does not coincide with the attacking stage of the insect. Resistance can also be categorized by the nature of the plant-pest interaction. Resistance can result from **antixenosis** (*anti* meaning "against" and *xenos* meaning "stranger"), in which plant features

Table 3. Effects of Crop Rotations on Insect Pests

Rotation	Insects managed	Problem insects	Additional notes
Continuous corn	Wireworms and white grubs are usually less problematic because of control by soil insecticides applied for corn rootworms and because adults prefer to deposit eggs in other crops.	Western and northern corn rootworms frequently occur at damaging population levels whenever corn follows corn. This problem outweighs other rotation effects on pest insects.	Black cutworm moths lay eggs less often in corn stubble than in soybean or wheat stubble. The likelihood of cutworm problems is therefore slightly reduced in continuous corn.
Corn after soybeans	Western and northern corn rootworms are managed by any rotation that disrupts continuous corn. Wireworms and white grubs usually do not build up to damaging levels in a corn-soybean rotation. Avoiding continuous soybeans reduces the prevalence of grape colaspis.	Black cutworms may be slightly more prevalent in corn after soybeans than in continuous corn, but the effects of rotation are secondary to weediness at the time moths deposit eggs. (Weedy fields in March and April are most likely to suffer cutworm damage later.)	Most soybean pests are not influenced by rotation with corn.
Corn after wheat	Western and northern corn rootworms are managed by any rotation that disrupts continuous corn.	Armyworms, wireworms, and white grubs may infest wheat and subsequently become economically damaging to corn, especially under reduced tillage.	
Corn after alfalfa (or clover or other hay)	Western and northern corn rootworms are managed by any rotation that disrupts continuous corn.	Wireworms and cutworms are more common (but still sporadic) after legumes and other perennial crops. Grape colaspis may become economically damaging to corn after red clover.	
Corn after sod or set-aside	Western and northern corn rootworms are managed by any rotation that disrupts continuous corn.	Wireworms, white grubs, corn billbugs, cutworms, armyworms, and sod webworms are more common where reduced tillage is practiced.	

Table 3. Effects of Crop Rotations on Insect Pests (cont.)

Rotation	Insects managed	Problem insects	Additional notes
Continuous soybeans	None	Grape colaspis, as well as diseases and nematodes, are favored by continuous production of soybeans.	
Continuous wheat	None	Hessian fly infestations may build up if fly-free dates are not observed and resistant varieties are not used. Armyworms may become more damaging.	Diseases that persist from season to season generally prevent continuous wheat production.

discourage certain insects from initially infesting the crop; this type of resistance is also called nonpreference. **Antibiosis** (*anti* meaning "against" and *bios* meaning "life") refers to mechanisms that involve chemical defenses that kill the insect or prevent it from developing properly after it begins feeding. **Tolerance,** the ability to withstand infestation and feeding damage without yield reduction, is also a form of resistance. Resistance mechanisms are mentioned briefly in Table 4 along with other information on resistant varieties.

Benefits and Drawbacks of Resistant Varieties

Most farmers in Illinois choose crop varieties primarily according to their yield potential and the time required to reach maturity ("shorter season" varieties for cooler climates of northern areas). Although resistance to pathogens (for example, cereal rusts and the soybean cyst nematode) may determine the selection of a particular variety, only rarely is resistance to insects considered. Even so, planting resistant varieties where they are available and productive offers many benefits. Insect resistance does not interfere with other pest management practices such as tillage or the application of insecticides. These tactics remain effective and do not compromise the benefits provided by resistance. In some instances, resistance may slow insect development or population increase so that other management practices (for example, cultural controls, action of beneficial insects, and planting or harvesting dates) become more effective, or insecticides can be used less frequently or at reduced rates, or both. Also, there is generally little or no added cost involved in growing a resistant variety.

For a number of reasons, the use of insect-resistant varieties (like the use of insecticides) is not a complete and simple answer to every pest problem. Many resistance factors convey resistance to only one species of insect. Efforts to use such factors in the development of commercial varieties must avoid the inadvertent development of a variety with increased susceptibility to other insects or diseases, and additional pest management tactics must be used to deal with other pests that attack the resulting variety. Varieties resistant to a certain pest sometimes yield less than susceptible varieties when infestations of that pest do not develop. Lower yields may occur because plants devote resources to resistance mechanisms (not yield) that provide no benefit in the absence of the pest. Of course, the same resistance mechanisms allow the plant to survive and produce a crop with reduced pesticide costs when the pest is present. The payoff of resistant varieties, therefore, is greatest when the target pest occurs in most fields during most crop years. Problems also result from the fact that resistance genes may be difficult or impossible to locate in related wild species or may be difficult to transfer into a crop plant by conventional breeding techniques without altering important agronomic traits in the process.

Populations of insects can evolve in response to resistance mechanisms in plants and subsequently damage previously resistant varieties. Insect populations that have evolved to overcome the resistance mechanisms of plants are known as biotypes. Biotypes develop most frequently in response to plant chemical resistance factors that are controlled by a single gene (just as insecticide-resistant populations of pests evolve in response to compounds that interfere with specific metabolic steps). Physical factors, such as hairy or tough leaves, and resistance factors that are

Table 4. Insects Managed by the Use of Resistant Crop Varieties

Crop	Insect	Nature of resistance
Corn	European corn borer	Screening trials conducted by seed companies since the 1960s have selected varieties less susceptible to infestation, stalk breakage, and yield reduction. Resistance factors have not always been identified. In some varieties, high levels of DIMBOA and other factors in young corn plants cause mortality of first-generation corn borers. Other unidentified factors cause reduced tunneling by second-generation borers. See Chapter 1, "Insect Pest Management for Field and Forage Crops," for a partial list of resistant varieties and additional information.
	Corn rootworms	Varieties with larger root masses and greater compensatory regrowth of roots show some tolerance in the form of greater "standability" or reduced lodging. Data on varietal differences in rooting habits or rootworm resistance are not available.
Soybean	Potato leafhopper	Hairiness (pubescence) of stems, leaves, and pods deters feeding by potato leafhoppers.
	Spider mites	In variety trials conducted in 1988 (during a severe outbreak of the twospotted spider mite), the variety Burlison was the least damaged. The source of its possible resistance or tolerance has not been identified; its performance under rigorous screening for resistance to spider mites has not been evaluated.
	Bean leaf beetle and Mexican bean beetle	Hairiness may deter pod-feeding beetles. An experimental Maturity Group III germ line resistant to foliage feeders in general (bean leaf beetle, Mexican bean beetle, and others) has been identified in breeding programs at Purdue University. Resistance factors have not yet been incorporated into agronomically acceptable commercial varieties.
Wheat	Hessian fly	Although 20 different resistance genes have been identified, only 5 have been deployed in commercial varieties. Resistance genes H7-H8, H3, H5, and H6 are used in current varieties. Hessian fly biotype L (predominant in collections from Illinois in 1987 and 1988) has overcome all of these genes; biotype J infests all varieties except those using the H6 gene. Efforts to deploy other resistance factors in suitable varieties are ongoing. Residue destruction, crop rotation, and strict adherance to fly-free planting dates are especially important in the absence of effective resistance.
Alfalfa	Aphids (spotted alfalfa aphid, pea aphid, blue alfalfa aphid)	Physical factors, especially hairiness (pubescence) and glandular trichomes (hairs associated with secretory structures) interfere with aphids' abilities to feed. Chemical factors convey nonpreference and cause early mortality. In the case of the blue alfalfa aphid, tolerance is the main mechanism of resistance.
	Potato leafhopper	Hairiness and glandular trichomes interfere with feeding and egg laying. Saponins and other chemical factors may convey nonpreference. Lignification (hardening) of stems may reduce egg laying.
	Alfalfa weevil	Tolerance is conveyed by heavy terminal growth and axillary branching. There are no truly resistant varieties available, although glandular trichomes may hinder early larval feeding.

determined by multiple genes are less likely to favor the development of new pest biotypes.

Because pests can overcome resistance mechanisms, developing a resistant variety is not a one-time effort. For example, the Hessian fly (Figure 4) has been considered a minor pest of wheat in recent years because of the availability of resistant wheat varieties and because of the practice of delaying fall planting until after "fly-free dates" (see wheat section in "Altering Planting or Harvesting Dates" later in this chapter). Although approximately 20 genes for Hessian fly resistance have been identified in wheat, only 5 have been deployed in public and private wheat varieties. Biotypes of the Hessian fly have developed in response to these resistance genes, and Hessian fly infestations can now be observed in all commercial varieties. Several years may elapse before breeding programs can incorporate additional resistance genes into new varieties with acceptable agronomic traits. Until new varieties with new resistance mechanisms are available, planting previously resistant varieties is recommended (see Table 5), but planting after established fly-free dates is especially important. Table 4 lists the pests for which resistant varieties are available and the mechanisms of resistance. Table 5 lists some current resistant varieties.

New Technologies and Crop Resistance

New techniques in tissue culturing and genetic engineering offer new opportunities for deploying

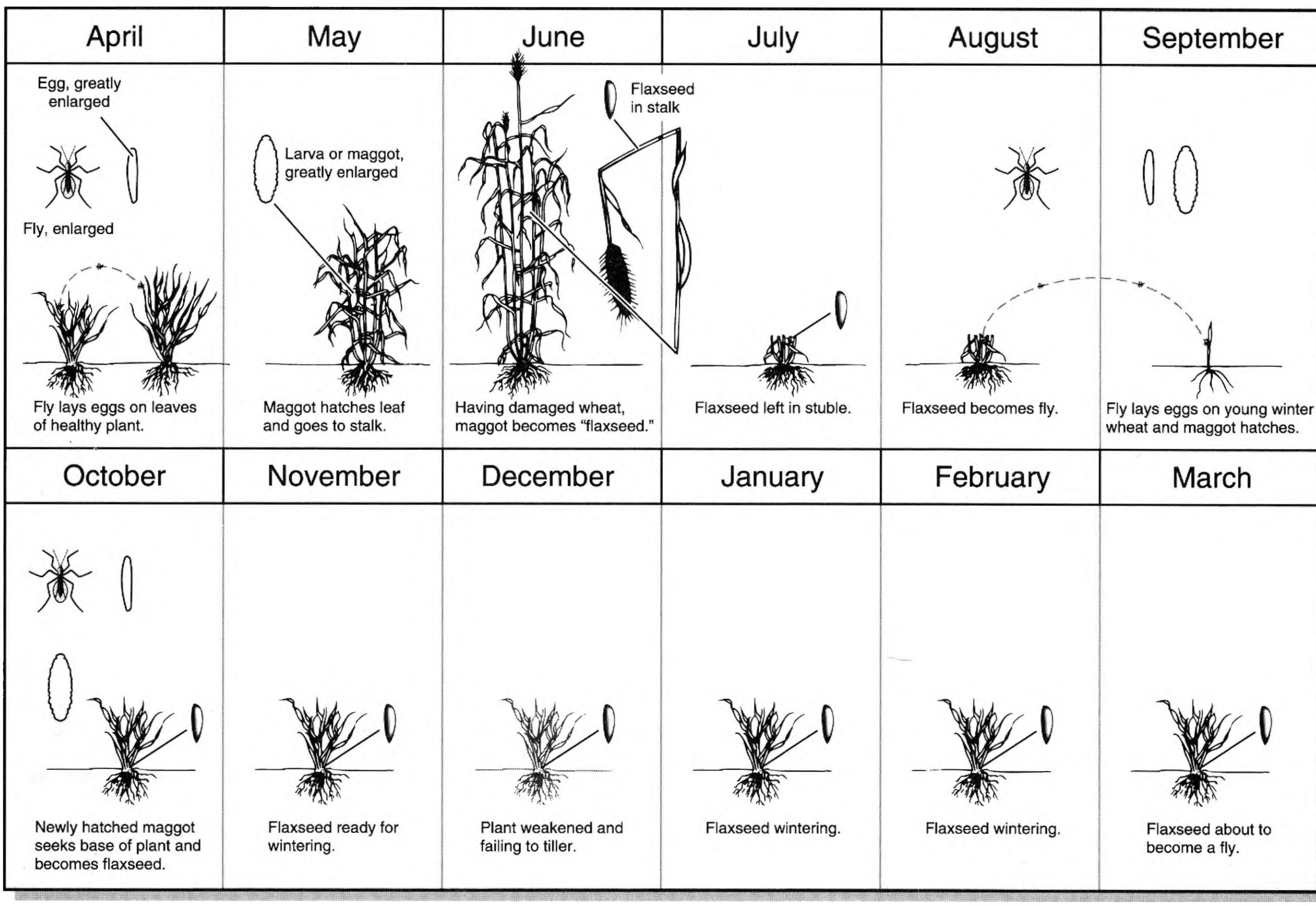

Figure 4. The Hessian fly. Hessian flies overwinter inside a puparium or "flaxseed" at the base of wheat plants. Flies emerge in the spring, mate, and deposit eggs on the leaves of winter or spring wheat. Larvae feed between the leaf sheath and stem, causing discoloration, abnormal tillering, yield reductions, and easier breakage and lodging of stems. Larvae pupate in the early summer, and another generation of adults emerges in late summer, mates, and deposits eggs on wheat if it is available. Destroying wheat stubble and volunteer wheat and delaying fall seeding until after "fly-free dates" disrupts this life cycle. (Illustration from USDA Farmers' Bulletin 1627.)

resistance genes into crop plants. (For background information on genetic engineering techniques, see Gasser & Fraley 1989.) Although conventional crop breeding and variety development programs represent a form of "genetic engineering," recently developed techniques for the transfer of genes promise a revolution in applied genetics. The benefits of such techniques in the field of plant resistance include their relative speed and their specificity in comparison with traditional breeding programs; they also offer ways to transfer genes among separate species (transgenics).

The degree of genetic engineering that might be possible with new techniques includes such "minor" changes as more easily identifying specific resistance genes in a crop species and incorporating them into a current variety without compromising its desirable agronomic traits. If such an approach could be used to deploy already known genes for Hessian fly resistance into current varieties, the time required to develop new resistant varieties might be reduced substantially. Although incorporating foreign genes for resistance into the genetic code of an existing variety is possible, it is neither commonplace nor simple.

More dramatic steps involving the transfer of a gene from one species to another are exemplified in the production of *Bacillus thuringiensis* (*Bt*) endotoxin in corn. *Bt* is a bacterium; different strains produce crystalline protein toxins that are poisonous to different groups or species of insects. Because these specific toxins are virtually nontoxic to vertebrates and most nontarget insects, they have been developed as safe and effective insecticides. Gene transfer techniques have been employed to produce corn plants that contain *Bt* toxins for caterpillar (including European corn borer) control. Although the *Bt* gene that controls the production of the insecticidal protein has not been inserted directly into the corn genome, the toxin-controlling gene has been transferred to another bacterium that grows within corn tissues. Where this genetically altered bacterium has been used to inoculate corn seeds or plants, the corn plants subsequently contain sufficient toxin to protect the plant against corn borers.

Using *Bt* genes for plant resistance to insects opens new doors for advancements but also poses new problems. If corn varieties containing a *Bt* toxin are used widely, it seems likely that European corn borer populations will develop resistance to this very specific insecticidal compound. Although corn borers might eventually develop resistance to *Bt* as a result of its application to plant foliage, this outcome is less likely because only a small portion of the Midwest corn crop is treated for corn borer control. (Where the majority of a pest population is not exposed to an insecticide, the evolution of resistance to that insecticide is less likely.) In this instance, genetically engineering *Bt*-based corn borer resistance into corn might speed the development of corn borer biotypes that cannot be controlled by *Bt*. These and other pitfalls associated with biotechnological advances in genetics do not preclude the beneficial application of these new technologies; they simply illustrate the need to consider a wide range of possible results.

Altering Planting or Harvesting Dates

The timing of planting or harvesting influences infestations of several pests. The degree to which planting or harvesting dates may be altered without adversely affecting crop performance, however, is constrained by many factors (for example, soil temperature early in the season, rainfall and soil moisture, tillage method, and crop variety). Altering planting dates may also involve trade-offs among pests because changes designed to reduce damage from one pest may expose a crop to additional risk from a different pest. The most practical way to examine the effects of planting and harvest dates is to discuss major crops individually.

Corn

Benefits of early planting. Planting corn as soon as possible after the risk of frost damage has declined is often advised for maximum yield. Planting early sometimes allows corn to escape serious damage from black cutworm. This benefit comes about because weeds are removed by tillage before immigrating moths lay eggs in early fields, and corn may develop beyond a vulnerable growth stage before cutworm larvae reach a damaging stage in their development. The influence of planting date on black cutworm damage varies according to the dates on which black cutworm moths immigrate into an area from the south each spring. Earliest plantings in any area are usually least damaged by the season's second generation of European corn borer (Figure 5) because moths laying eggs for the second generation usually prefer the least developed (latest planted) corn available. Tasseling and pollination sometimes occur in early plantings before corn leaf aphids or corn rootworm beetles become numerous, but this result is rarely important enough to influence planting time decisions.

Drawbacks of early planting. Damage caused by seedcorn beetles, seedcorn maggots, and wireworms is greatest when seed germination is delayed in cold,

Table 5. Wheat and Alfalfa Varieties Marketed as Resistant to Specific Pests

Soybean varieties with partial resistance to certain insect pests are not listed because differences in levels of resistance among commercial varieties are insufficient to form the basis for variety selection. This list may not include all resistant varieties available.

Crop[a]	Variety	Merchant	Insect resistance
Wheat	Arthur	Public	Hessian fly[b]
	Auburn	"	"
	Becker	"	"
	Caldwell	"	"
	Cardinal	"	"
	Clark	"	"
	Magnum	"	"
	FS 404	Growmark	"
	FS 414	"	"
	FS 415	"	"
	FS 417	"	"
	Coker 9766	Northrup King	"
	McNair 1003	"	"
	2550	Pioneer	"
	2555	"	"
Alfalfa	Most varieties	Various	Potato leafhopper (tolerance or some degree of resistance)
	Perry	Public	Alfalfa weevil (tolerance or some degree of resistance)
	Promise Alfalfa	Americana	"
	DK135	DeKalb-Pfizer Genetics	"
	Sabre	Allied Seed/Agway	"
	K-5 Brand	George Keller & Sons	"
	Vancor	Northrup King	"
	Team	Public	"
	Liberty	"	"
	Cimarron	George Keller & Sons	"
	Cimarron VR	"	"
	GH 747 (LL 3510)	Golden Harvest	"

[a]See Chapter 1, "Insect Pest Management for Field and Forage Crops," for a discussion and partial listing of corn varieties resistant to European corn borer.

[b]Hessian fly biotype L has overcome the resistance genes used in all the wheat varieties listed in this table. Using these varieties may reduce overall Hessian fly damage by preventing infestation by other biotypes, but no currently deployed resistance genes provide complete protection.

wet soils. Damage from first-generation European corn borer is usually greatest in the most mature fields (those planted earliest) in a given area because moths laying eggs for the first generation prefer to deposit their eggs on whorl-stage corn with an extended leaf height of at least 18 inches.

Benefits of late planting. In contrast to the results of planting early, planting later reduces the risk of damage caused by seedcorn beetles, seedcorn maggots, wireworms (somewhat), corn rootworm larvae, and first-generation European corn borer.

Drawbacks of late planting. Corn planted later than average is most likely to be damaged by black cutworm and second-generation European corn borer. The latest fields in an area are also most attractive to corn rootworm beetles. Although silk feeding by these beetles is greatest in late fields, damage rarely is severe enough to warrant treatment. When present in higher concentrations in late fields, beetles do, however, deposit large numbers of eggs in the soil, and corn planted in these fields the next year will likely be damaged by rootworm larvae. Perhaps the greatest problem associated with late planting is that, under average rainfall and temperature patterns, delayed plantings do not yield as well as earlier plantings.

Soybeans

Planting dates have only minor impacts on insect and mite pests of soybeans. Later-than-normal plantings of soybeans sometimes escape damage from overwintered adult bean leaf beetles that feed on soybean seedlings. They also suffer less preemergence damage from seedcorn maggots and damping-off fungi that sometimes reduce crop stands in cool, wet soils. Later plantings may be more vulnerable to pod damage from late-summer infestations of bean leaf beetles, stink bugs, and grasshoppers. Noting which pests are most common in early or late plantings of soybeans is appropriate, but because these pests rarely occur at levels requiring control, these observations do not justify any alteration in planting schedules.

Wheat

Planting date is extremely important in the management of wheat insects, especially the Hessian fly (Figure 4). Adult flies emerge from wheat stubble in the autumn and lay eggs in wheat seedlings. If wheat seedlings emerge from the soil after the flies have ended their activity and died, the crop will be free of Hessian flies. Periods of Hessian fly activity have been recorded throughout Illinois and other wheat-producing states, and "fly-free dates" have been established. In Illinois, these dates range from September 17 near the Wisconsin border to October 12 at the southern tip of the state. NHE-152 (*Hessian Fly*, see *References*) lists fly-free dates for Illinois counties. Seeding after these dates also avoids most virus-carrying aphid infestations.

When susceptible wheat varieties are seeded before fly-free dates or where volunteer wheat is available, infestations of Hessian fly become established in the fall. Larvae feed at the base of wheat plants and later pupate and overwinter. Adults emerge in the spring and lay eggs on winter or spring wheat where further damage is caused by larvae feeding between the leaf sheath and stem. This generation produces the adults that emerge from stubble to infest seedling wheat in the late summer or early fall.

When producers adhered to fly-free planting dates and used wheat varieties resistant to the Hessian fly, this pest caused only minor damage for many years. Perhaps because of declining awareness of the importance of the Hessian fly, in recent years many farmers have seeded wheat before fly-free dates, thereby risking the development of Hessian fly biotypes able to overcome the resistance mechanisms of varieties now in use. Wheat has also been used as a cover crop in set-aside acreage, and varieties susceptible to the Hessian fly often have been planted. As a result, the prevalence of Hessian fly has increased, and biotypes of this pest now infest previously resistant varieties (see Table 5). Considerable reductions in yield may result from Hessian fly infestations; these losses are often mistakenly attributed to disease or climatic factors. Adhering to fly-free planting dates and destroying volunteer wheat and wheat in set-aside acreage in late summer is required to manage this reemerging problem.

Alfalfa

Although planting date has little effect on insects in alfalfa, the alfalfa weevil and potato leafhopper can be managed in part by the timing of harvest. An early first cutting often reduces larval alfalfa weevil populations by exposing the larvae to sunlight, drier conditions, and increased predation. Early cuttings might be especially appropriate where insecticide applications would otherwise be needed and the planned harvest is only a few days away. Loss in yield due to early cutting might be offset by savings in insecticide costs. In addition, required intervals between insecticide application and harvest prohibit the use of certain insecticides in such a situation. Harvesting affects leafhopper populations in second and third cuttings by removing

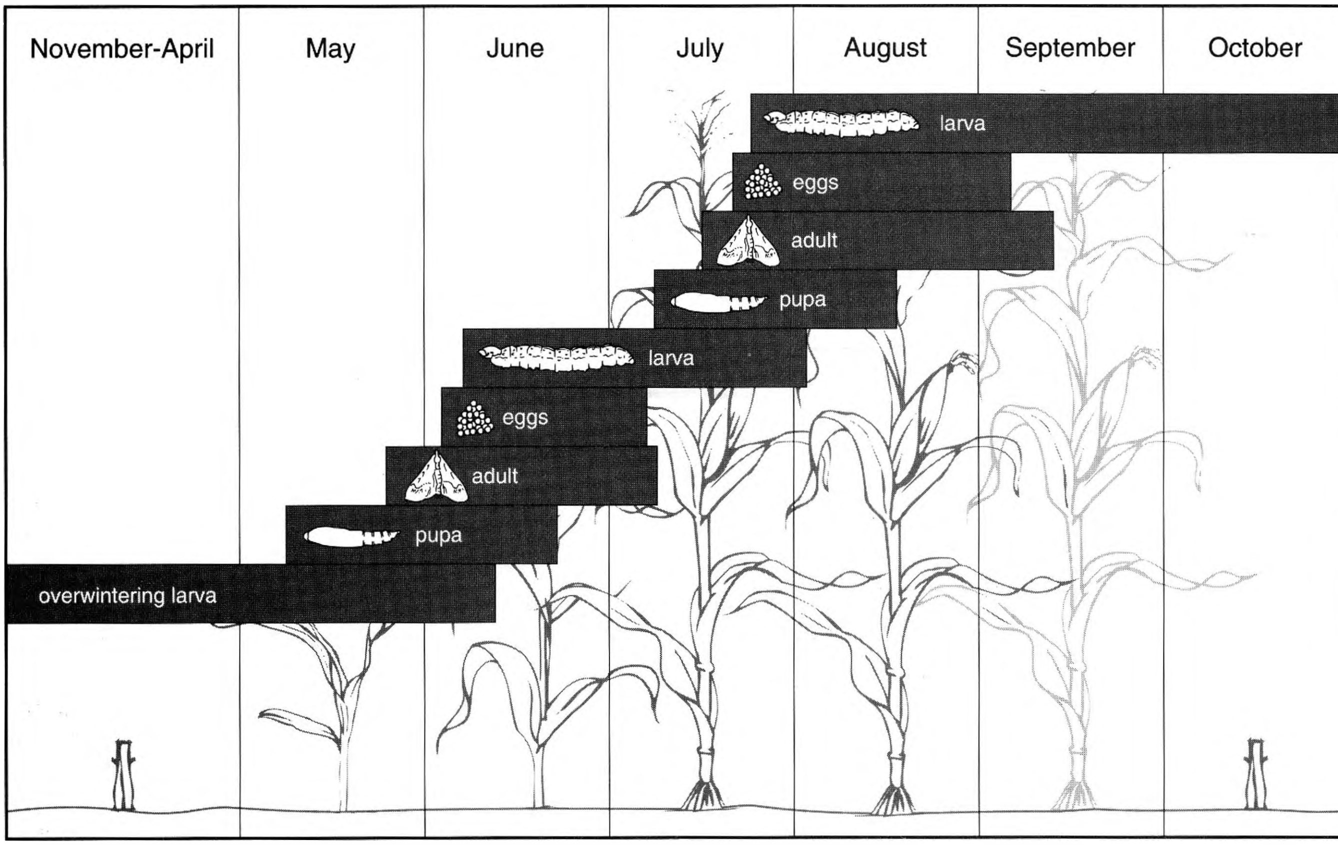

Figure 5. Life cycle of the European corn borer in Illinois. Larvae overwinter in cornstalks before pupating in May. Moths deposit eggs on whorl-stage corn, usually in June, and first-generation larvae develop within corn plants in June and July. These larvae give rise to a second moth flight that spans August. These moths deposit egg masses on leaves; larvae bore into stalks to feed and subsequently pass the winter. (Illustration adapted from North Central Regional Publication No. 327, Iowa State University, Ames.)

leafhopper eggs from the field along with the hay crop and by killing many immature leafhoppers. This contribution to leafhopper control does not provide the basis for setting a harvest schedule, but it does point out that infestations are reduced somewhat by harvesting. Because leafhoppers are mobile enough to reinfest fields after harvest and because alfalfa regrowth is especially susceptible to leafhopper damage, sampling to determine leafhopper densities is especially important a few days after cutting.

Trap Crops

Insect infestations can sometimes be manipulated by planting trap crops that attract pests away from the remainder of a field or area. Trap crops used in such a manner exploit the feeding or egg-laying preferences of individual species. These trap crops may be plant species that are especially attractive to the target pest; sometimes the usual crop species itself can be planted especially early or late to serve as a trap crop. After insects have been attracted to the trap crop, it may be treated with an insecticide or destroyed to control the pest population without treating an entire crop or field.

Plants that serve as trap crops have been identified for several pests. For example, blooming squash and pumpkins and late-planted corn attract corn rootworm beetles, drawing them away (somewhat) from mature corn in nearby fields. Snap beans (green beans) draw concentrations of bean leaf beetles from adjacent soybeans. In practice, however, the specifics of using these and other trap crops for controlling field crop insects are cumbersome or not well established.

Problems associated with the use of trap crops often involve issues of scale; attracting a high percentage of pests from vast acreages of corn, for example, would require numerous plantings of trap crops. Although densities of corn rootworm beetles are great in the trap crops listed above, beetle densities in surrounding fields are often influenced only slightly by any migration to small acreages of trap crops. Questions regarding how many strips or patches of trap crops and how far apart these crops could be planted remain unanswered. Consequently, land and other resources are seldom devoted to the production of trap crops. Using set-aside acreage to grow strips or plots of trap crops might be practical if effective trap crops are identified.

Reduced Tillage

Reduced tillage systems are usually adopted to limit soil erosion, soil compaction, and the expenses associated with conventional tillage practices (mostly equipment, fuel, and labor). Tillage operations might be described as traditional or conventional tillage (moldboard plowing or chisel plowing and disking so that nearly all crop residue is incorporated); reduced tillage (at least 30 percent of the soil surface remains covered by crop residue); strip tillage and ridge tillage (approximately one-third of the soil surface is tilled for seeding the new crop, whereas in ridge tillage the rows are raised); paraplowing (the soil and crop residue is lifted and loosened, but not inverted); or no-tilling (the new crop is seeded into narrow slits in the soil with no other disturbance of crop residues).

Tillage affects certain insect populations because it alters the soil and crop environment in which they develop. Tillage alters soil structure (porosity and bulk density, for example), displaces crop residues, and moves weed seeds, pathogens, and soil insects up or down in the soil profile. It also destroys weed seedlings, incorporates organic matter, and influences soil aeration, soil moisture, and soil temperature.

Reduced tillage contributes to cool soil temperatures (compared with conventionally tilled fields) early in the crop season because crop residues slow the warming process by insulating the soil surface and reflecting solar radiation. Under reduced tillage regimes, soil moisture is conserved somewhat because crop residues shade the soil surface. In general, no-till produces a more stable soil environment for pests and beneficial insects alike.

The insects most affected by changes in tillage practices are those that overwinter in the soil and become active during the early stages of crop growth. Soil- and litter-dwelling insects are affected more than foliage-feeding insects. In most instances, a greater diversity of insects is present under reduced tillage, but this greater diversity does not always result in predictable increases or decreases in crop damage because both pests and their natural enemies respond to tillage practices. Because generalizations about the effects of tillage provide little guidance for pest managers, pest-specific information is presented in Table 6. A few key observations from Table 6 are included in the following paragraphs.

- **Black cutworm** moths (Figure 6), migrating into Illinois in the spring, prefer to lay their eggs where unincorporated crop residues and weeds (especially chickweed) are present. Although cutworm infestations in corn are not always greater in reduced tillage systems, reducing tillage may promote increased densities of weeds in fields before corn is planted. Consequently, the risk of cutworm infestations in corn is higher in reduced tillage programs when early spring weed growth attracts moths.

- The **stalk borer**, another caterpillar pest of corn, is more numerous in and adjacent to areas where grassy weeds remain standing from the previous season. In the spring this insect feeds in those grasses (where eggs were deposited the previous August) until it "outgrows" them or until these weeds are controlled by herbicide application. The stalk borer then moves into corn. Where reduced tillage allows the persistence of grassy weeds from one season to the next, the stalk borer can cause severe damage.

- **Slugs**, not often considered economically important in Illinois field crops, are most common in reduced tillage or no-till fields in the southern one-third of the state. Crop residues on the soil surface provide a food source for slugs throughout the winter and early spring; these residues also help maintain cool, moist conditions that favor slug survival as these pests feed on seedling corn or soybeans.

- **European corn borer** infestations are influenced by tillage primarily on an area-wide basis. Corn borers overwinter as mature larvae in cornstalks; tillage actions that break up or bury cornstalks reduce overwintering survival. As the use of reduced tillage becomes more widespread in any given area, corn borer populations will likely increase (how great an increase is difficult to predict). Yet because corn borer moths are very mobile, flying from field to field during egg laying, the impacts of tillage are not confined to a single field, regardless of the tillage practice employed.

Cover Crops

Cover crops, usually grasses or legumes planted to

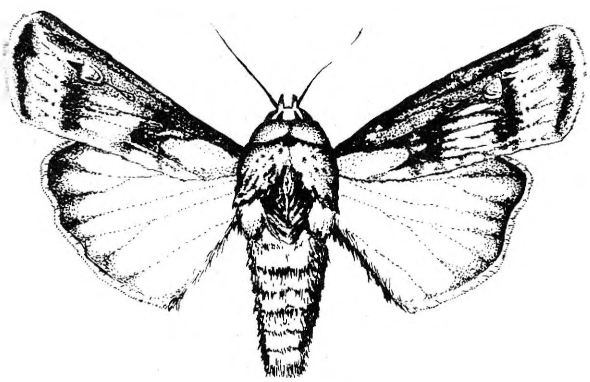

Figure 6. Black cutworm moth. Moths migrate into Illinois each spring, beginning in March. They deposit eggs in fields before corn is planted, choosing especially those fields with early season infestations of chickweed and other winter annuals. A statewide monitoring program indicates the timing and intensity of moth flights so that recommendations can pinpoint when and where to sample for cutworm presence and damage. (Illustration adapted from Practical Insect Pest Management, Vol. 2, by M.C. Wilson et al., Waveland Press, Prospect Heights, Illinois.)

provide ground cover during the period between primary crop seasons, provide a variety of benefits. They control soil erosion and contribute to soil tilth and organic matter; they also reduce weed populations by shading or by production of allelopathic chemicals that inhibit the growth of certain other plant species. Legumes used as cover crops supply nitrogen. Typical cover crops include various clovers, hairy vetch, ryegrass, rye, wheat, and oats.

Cover crops are treated with herbicides or mechanically destroyed (by mowing or tillage) to allow the production of a subsequent crop. Where tillage is used, the cover crop may be completely incorporated by plowing or partially incorporated by disking. In no-till fields where herbicides or mowing is used to kill the cover crop, plant residues are left on the soil surface. The effects of cover crops on insect populations vary greatly among insects and according to the particular cover crop and its management (especially the time of seeding and the time and method of destruction).

In certain situations cover crops contribute to pest problems. Where corn is planted in no-till systems following grass cover crops (rye, wheat, etc.), the likelihood of armyworm infestations is greatly increased. Armyworm moths lay their eggs on the grass cover crop, and larvae subsequently move from the cover crop to feed on corn. Slugs are also favored by the presence of cover crops (for the reasons listed in conjunction with reduced tillage), especially in southern portions of Illinois and during cool, wet springs.

In general, in fields where cover crops are grown, the number and diversity of insects is greater than usual (where no cover crop is used) when those fields are prepared for the establishment of a subsequent crop. This increase is especially apparent in hairy vetch. Although studies have shown that beneficial species and certain pests are more prevalent after cover crops, no consistent trends for increases or decreases in overall pest damage are apparent. When cover crops are used in Illinois, the "bottom line" advice concerning pest management is to be wary of armyworms and slugs and to monitor the subsequent crop closely for other pests and beneficial insects.

Intercropping

Intercropping, the practice of growing two or more crops simultaneously in the same field, can vary in form from mixed intercropping (no separate row arrangement) to row intercropping (alternating single rows) to strip cropping (alternating multiple rows). Mixed intercropping is practiced mostly in the tropics. Row intercropping, generally too labor-intensive for field crops, can be used even in the United States in the production of high-value horticultural crops. For field crops in the Midwest, strip intercropping (four or more rows per strip) is the primary alternative to monocultures (fields of only one crop). Relay cropping, in which a second crop is seeded into an existing standing crop shortly before it is harvested (for example, seeding soybeans or a legume into standing wheat) might be considered as a form of intercropping, but relay crops share the same field for only a short time.

Why is intercropping important in pest management? Intercropping is one way to increase the diversity of plant species, herbivorous insects (plant-eaters), and insect predators and parasitoids in a field. Ecological research indicates that, in general, diverse ecosystems are more stable, in part because predators and parasitoids regulate pest populations and in part because certain pests are less able to locate host plants in mixed crop stands. Consequently, the increased diversity provided by intercropping is sometimes advocated as a way to minimize pest problems. Whether or not practical approaches to intercropping offer real benefits in Midwest field crops has not, however, been demonstrated.

A review of 150 studies of insect populations in agricultural systems with increased diversity found that 53 percent of 198 plant-eating species encountered in these studies were less abundant in more diversified systems (see Risch et al. 1983). Of the remaining species, 18 percent were more abundant in diversified systems, 9 percent were equally numerous in diversified and conventional systems, and 20 percent increased in some studies and decreased in others. Although the majority of the studies showed lower numbers of herbivorous insects (pests), only 19 of the 150 studies compared crop yields from the diversified and conventional systems. Yields were greater in the diversified system in 4 of the 19 studies, lower in the diversified system in 9 studies, and variable in the remaining 6 studies. Because crop yields (balanced with inputs), not the densities of pests or beneficial species, indicate the success of a crop production system, this review indicates that the benefits of diversification remain unclear. In sum, results from these studies suggest that much is to be learned in the application of ecological theories concerning crop diversity.

Although relevant data are available on very few mixed intercropping efforts in the Midwest, strip cropping can be practiced with little variation in typical production practices. For example, some farmers in northern Illinois have contour-planted alternating strips of corn and soybeans to allow crop rotation without excessive soil erosion on rolling hills. While this application of strip cropping offers clear benefits, it does complicate the selection and use of herbicides.

Recent studies conducted in Illinois (see Oloumi-Sadeghi et al. 1989) indicate that the presence of grassy weeds in alfalfa is associated with reduced infestations of potato leafhoppers. (The moderate levels of grassy weeds in this research did not reduce alfalfa yield.) These results suggest direct benefits from at least minor reductions in weed control; intercropping grasses and alfalfa could also discourage leafhopper outbreaks where hay quality concerns and market demands can be met by such a blend of forages.

Research conducted in Ontario, Canada, has shown reductions in European corn borer infestations in corn where red clover was interseeded within 10 days of corn planting (see Lambert et al. 1987). Corn yields were not reduced in the mixed-crop fields. Although this approach to intercropping complicated weed control practices, it also improved soil fertility.

Controlling Pest Infestations

Although rotating crops, using resistant varieties, and altering planting or harvesting dates minimize problems caused by certain key insects, pest outbreaks still occur in some fields. Responding to such outbreaks with a minimum use of broad-spectrum insecticides requires (1) regular monitoring of crops to identify and quantify populations of pests and beneficial insects; (2) use of established thresholds that indicate the density of a pest that can be tolerated without economic damage; and (3) selection of the least toxic method that will effectively and economically reduce pest densities.

Monitoring Pest Populations

Monitoring or "scouting" fields for pest infestations involves a wide range of pest detection practices that differ for specific crops and pests. Sampling methods include the use of baited traps, a sweep net or ground cloth, and visual inspection of plant surfaces. Resource materials that describe pest scouting procedures for Illinois field crops include Chapter 1 of this *Handbook*, "Insect Pest Management for Field and Forage Crops," the *Field Crop Scouting Manual*, and the *Pest Management & Crop Development Bulletin* (a newsletter produced weekly from April through August). See the *References* section for information on these resources.

Thresholds for Control

Common insect pests of any given crop usually occur at some level in nearly all fields where that crop is grown. Yet in most fields these pests do not cause enough damage to warrant control. Determining the need to control a pest infestation usually involves comparing observed densities with estimates of economic thresholds for that pest. An economic threshold is the density of a pest that will, if uncontrolled, cause enough crop loss to offset the dollar costs (insecticide and application) of control.

Economic thresholds have been established or estimated for many insect pests of Illinois field crops. In some instances those thresholds are "dynamic," incorporating estimates of crop yield, crop value, and specific control costs. For other pests, control decisions are guided by "static" thresholds (constant over a range of circumstances) because knowledge of the pest's impact on the crop is insufficient to allow more precise calculations. The references cited above present information on thresholds for most field crop insects.

Because Illinois field crops are less valuable on a per-acre basis than horticultural crops such as fruits and vegetables, and because grains, soybeans, and forages are not subject to the strict cosmetic standards applied to fruits and vegetables, many pest infestations do not warrant control. Estimates of relatively infrequent use of insecticides on Illinois field crops

Table 6. Effects of Reduced-Tillage or No-Till Systems on Pests and Beneficial Insects

Crop and insect	Effect	Notes
Corn		
Corn rootworms	0	Adults lay eggs in late summer; subsequent tillage has little effect on the survival of eggs during most winters. In harsh winters with subnormal temperatures and subnormal snowfall, egg survival is somewhat greater in reduced tillage.
Wireworms	+	Increases in grassy weed populations, reduced soil disturbance, and delayed germination from cooler soil temperatures may aid wireworm buildup and damage.
White grubs	+	Increases in grassy weed populations and reduced disturbance of soil favor survival of true white grubs.
Black cutworm	+ to +++	Adult cutworm moths prefer to lay eggs in weedy fields and in fields with unincorporated crop residues. Increased populations of predators and parasitoids also develop, but an increase in cutworm damage often occurs anyway.
European corn borer	0 to +	Reduced tillage favors greater survival of corn borers in crop residue, but effects in specific fields are minor because moths disperse from emergence sites to lay eggs in suitable fields throughout the local area. Where reduced tillage leads to delayed planting or slower germination (cooler soil temperatures), corn may be less susceptible to attack by first-generation corn borers and more susceptible to second-generation damage.
Corn leaf aphid	0	
Armyworm	0 to +++	Ryegrass and other grass cover crops are especially attractive to egg-laying armyworm moths. In no-till systems where the grass cover is not plowed under, larvae move from the grass to feed on corn.
Stalk borer	0 to +++	Overwintering survival is greatest in reduced-tillage systems. In no-till fields, serious damage is most likely where grasses were present to attract egg-laying moths the previous August. If corn is no-tilled into soybean stubble where weeds were controlled during the previous year, stalk borers are not a problem.
Corn earworm	0 to +	If planting date or crop development is delayed in no-till fields, corn is usually more attractive to egg-laying moths. This is usually a very minor concern except for seedcorn producers.
Seedcorn maggot	+	Adult flies prefer to lay eggs where crop residue has been partially incorporated into soil. No-till corn stubble may be less attractive to egg-laying flies, but cooler, wetter soils shaded by crop residues slow germination and increase the period of vulnerability to seedcorn maggot injury.
Slugs	+++	Unincorporated crop residues and cooler, wetter conditions favor increases in slug populations and damage.

Table 6. Effects of Reduced-Tillage or No-Till Systems on Pests and Beneficial Insects (cont.)

Crop and insect	Effect	Notes
Soybeans		
Bean leaf beetle	0	Tillage has little effect on foliar feeding by bean leaf beetles.
Grasshoppers	0 to +	Tillage has little effect on foliar feeding by bean leaf beetles. Reducing tillage affects (favors) the survival of only those grasshopper species that lay eggs within fields. Those that lay eggs in weedy margins are not affected.
Spider mites	– to 0	Where crop residues help to retard soil moisture loss, plants may be less drought stressed than in conventional tillage; reducing drought stress slows mite outbreaks.
Slugs	+++	Unincorporated crop residues and cooler, wetter conditions favor increases in slug populations and damage.
Wheat		
Aphids	– to 0	Prior crop residues may decrease the attractiveness of new stands of wheat to airborne aphids in the fall. (Seeding wheat after Hessian fly–free dates avoids most fall infestations of aphids.) By spring, it is unlikely that prior crop residues affect aphid invasion.
Hessian fly	0 to +++	Hessian fly populations carry over where wheat stubble is not tilled and volunteer wheat is not controlled. Hessian flies from undisturbed stubble move to new wheat that is planted before fly-free dates. Hessian flies that infest volunteer wheat in the late summer and early fall overwinter in the volunteer plants and can move to additional fields in the spring (regardless of those fields' fall planting dates). No-till seeding of wheat into other crop residues poses no problem.
Alfalfa		
Various pests	– to +	Several insects damage new stands of alfalfa that are no-till seeded in the fall. No-till seedings in the spring (into grasses) are less damaged by potato leafhopper than conventional seedings are.
All crops		
Beneficial insects such as ground beetles, rove beetles, parasitic wasps, spiders, and ants	+ to +++	In general, reducing tillage (reducing disturbance of residues and the top few inches of the soil profile) favors the survival of ground beetles, rove beetles, spiders, and ants; these groups of insects contain a number of generalist predators that feed on other insects. Reducing tillage usually allows some increase in weed presence, at least during some portions of the season. The presence of flowering weeds provides nectar and pollen for parasitic wasps. Because the conditions that favor survival and reproduction of beneficial species also favor certain pests, increases in numbers of predators and parasitoids may or may not lead to a reduction in overall pest numbers or damage.

+++ = substantial increase in pest or natural enemy population; + = some increase; 0 = no effect;
– = some decrease in pest or natural enemy population.

(Pike et al. 1991) reflect this situation. Even though using economic thresholds does not result in intensive application of insecticides on Midwest field crops, producers should note that such thresholds do not incorporate environmental considerations (for example, possible wildlife poisonings or reductions in populations of beneficial insects) or concerns about such hard-to-predict events as the development of insecticide resistance or enhanced degradation that may be favored by frequent use of insecticides. Consequently, when insect infestations exceed established thresholds only slightly, producers may be wise to consider these long-term impacts and refrain from using pesticides in at least some situations.

Selecting Alternative and Conventional Control Methods

Alternatives in Insect Management: Biological and Biorational Approaches, North Central Regional Extension Publication 401 (Weinzierl & Henn 1991) presents a detailed summary of alternative approaches to insect management. Although the use of alternatives in field crop insect management is summarized briefly below, readers are encouraged to refer to this publication for additional details.

Alternative Control Methods

The microbial insecticides, those containing or derived from insect pathogens such as viruses, bacteria, fungi, protozoans, or nematodes, are attractive alternatives to conventional insecticides because each is somewhat selective (killing a comparatively narrow range of insects) and all are very low in toxicity to humans and other vertebrate animals. Of the microbial insecticides, preparations of *Bacillus thuringiensis kurstaki,* or simply *Bt,* are most widely used in field crops. Products such as Dipel, Javelin, and others kill caterpillars that eat the *Bt* spores or toxin applied to plant foliage. These *Bt* products kill only caterpillars; they do not control other types of pests. Because *Bt* must be ingested to be effective, the caterpillar pests that do not feed on treated surfaces of plants are difficult to control by normal applications of *Bt.* Pests that are effectively controlled by *Bt* include European corn borer in corn (first-generation control is better than second-generation control), green cloverworm and loopers in soybeans, and alfalfa caterpillar. Where liquid formulations of *Bt* are applied as sprays to control these insects, using ground sprayers maximizes spray coverage and improves control. Several other caterpillars such as cutworms, stalk borer, and fall armyworm are not controlled by conventional applications of *Bt.*

Currently, no other microbial insecticides are suited for use against insect pests of Illinois field crops. Efforts to develop preparations of the soil fungus *Beauveria bassiana* and the insect-pathogenic nematode *Steinernema carpocapsae* for the control of numerous soil insects, including corn rootworms, are ongoing, but no products are yet available for use in Midwest field crops.

The botanical insecticides, plant-derived compounds such as pyrethrum (and pyrethrins), rotenone, sabadilla, ryania, limonene, and linalool, are of interest as alternatives to synthetic insecticides primarily because they break down rapidly in the environment, thereby posing little or no threat as long-term environmental contaminants. Although there are exceptions, most botanical insecticides are lower in toxicity than commonly used synthetic insecticides.

Although botanical insecticides are used to control pests of livestock, pets, and garden plants, their use in field crops is rare, in part because of limited supplies and high costs. Nonetheless, a few specific products are used in organic production systems. Ryania has been used to provide some control of European corn borer (*Bt* treatments are cheaper and more effective), and rotenone controls leaf-feeding beetles in a number of crops. Pyrethrins can be used for the control of a broad range of insects, but their rapid breakdown (within a few hours) usually renders them ineffective in field crop applications.

Insect attractants and traps are widely used in monitoring field crop pests; however, their use for direct control (mass trapping, mating disruption, or with toxic baits) is less common. Hundreds of attractant-baited traps are used to detect the spring immigration of black cutworm moths into Illinois each year so that producers throughout the state know when to monitor fields for this pest. (Information provided by this trapping program is distributed weekly in the *Pest Management & Crop Development Bulletin;* see *References.*) Traps can also be used to determine the seasonal timing and relative density of European corn borer moth, corn rootworm beetle, and corn earworm moth flights. For extensive details on the use of attractants and traps in insect management, see North Central Region Extension Publication 401 (Weinzierl & Henn 1991).

The combination of an attractant and an insecticide has led to the development and registration of a new poison bait marketed under the trade name Slam and a similar product named Compel, both for the control of corn rootworm beetles. The potential benefits of such a product include its specificity (killing only the species attracted to the bait) and its limited impact on environmental quality (much less insecticide is needed when an attractant effectively draws the pest to the poison). Planned improvements in the combination of attractants and the formulation of Slam are expected to increase its effectiveness in field applications.

Beneficial insects and mites include the predators and parasitoids that attack pests. Although commercial distributors sell a wide range of insect predators and parasitoids, few (if any) species are known to provide meaningful levels of control of field crop pests. Any purchase and release of beneficial insects has to be considered experimental; existing data are inadequate for developing concrete recommendations on release rates for parasitoids and predators.

For producers interested in purchasing beneficial insects despite the uncertainties, two "best choices" exist. Larvae of the green lacewing *Chrysoperla carnea* prey on aphids, caterpillar eggs, mites, and a range of soft-bodied insects. Where this insect has been released at rates of 50,000 to 100,000 eggs per acre in each of two or three weekly releases, it has provided control of certain caterpillar and aphid pests in corn and cotton. Tiny parasitic wasps in the genus *Trichogramma* attack other insects' eggs and have been used experimentally to reduce European corn borer infestations in corn. For first-generation control, three weekly releases of 100,000 *Trichogramma* per acre should begin as soon as corn borer moths are captured in light or pheromone traps. Control of second-generation corn borers may require higher release rates or a longer release period or both because corn borer egg laying usually extends over a longer period. Although *Trichogramma pretiosum* is sold for use in field crops, *Trichogramma nubilale* (not available commercially) is likely to be more effective against European corn borer.

Where short-term reduction of a pest population is needed, it is important to note that predators and parasitoids must be released in extremely high numbers to be effective. Although high costs and limited supplies of laboratory-reared predators and parasitoids make high release rates impractical in many situations, purchasing and releasing small numbers of common beneficial insects is very unlikely to provide any meaningful impact on pest infestations. Because many questions about release rates, the suitability of laboratory-reared predators and parasitoids, and the degree of control obtainable by releasing natural enemies remain unanswered, practical approaches to maximizing the effects of natural enemies in field crops often concentrate on conserving existing populations instead of buying and releasing beneficial insects. Although no single step provides a simple way to conserve the broad range of beneficial insects that attack the many pests of field crops, a few generalizations apply.

- **Recognizing beneficial species and pests.** The identification of pests and beneficial species is the first step in determining whether or not control is necessary. North Central Regional Extension Publication 401 (Weinzierl & Henn 1991) and picture sheets available from the University of Illinois Office of Agricultural Entomology provide illustrations of many pests and beneficial species.

- **Minimizing insecticide applications.** Most insecticides kill predators and parasitoids along with pests. As a result, few beneficial species survive in numbers sufficient to have any impact on pest infestations that escape insecticide applications or develop shortly after insecticide treatments. The use of insecticides can be reduced by rotating crops, selecting appropriate planting dates, and planting resistant crop varieties. Where pest infestations do develop, treating only where infestations exceed established thresholds also avoids unnecessary use of insecticides.

- **Using selective insecticides or applying insecticides in a selective manner.** A selective insecticide is more toxic to certain insects than to others. Although the ideal insecticide might be one that kills only a single target species, few insecticides offer this degree of selectivity. Nonetheless, *Bt*, as mentioned above, is toxic only to caterpillars and is an effective option for European corn borer control in corn. Limiting insecticide applications to areas of a field where infestations exceed threshold levels might be viewed as a selective method of application.

- **Maintaining ground covers, crop residues, and standing crops.** Many natural enemies of pests require the protection offered by vegetation to overwinter and survive. Cover crops supply prey and sometimes pollen and nectar (important foods for the adults of some predators and parasitoids), and as discussed earlier, most studies indicate that natural enemies are more prevalent in no-till and reduced-tillage systems than in conventionally tilled fields. Beneficial species also move into crops from woodlots, windbreaks, fencerows, and unmowed grassy ditchbanks and waterways. Preserving these uncultivated areas contributes to the natural biological control of pests. Harvesting alternate strips of alfalfa on a schedule that allows several days of regrowth before the remaining strips are cut helps to keep natural enemies in alfalfa fields. (They must emigrate from the field or perish when the entire crop is cut.) Increasing crop diversity also influences natural enemy populations, as discussed earlier in conjunction with intercropping and strip cropping.

- **Providing pollen or nectar sources or artificial foods.** Adults of some parasitic wasps and certain predators feed on pollen and nectar. Plants with very small flowers (such as some clovers, Queen Anne's lace, and other plants in the family Umbelliferae) serve as good nectar sources for these beneficial insects. The presence of flowering weeds in and around fields may also favor natural enemies. Artificial food supplements containing yeast, whey proteins, and sugars can be used to attract or concentrate adult lacewings, lady beetles, and syrphid flies. Wheast, BugPro, and Bug Chow are examples of such food supplements available for purchase.

Practices that favor natural enemies must be judged according to their impact on pest populations and crop performance as well as their effect on natural enemies. Such practices may or may not lessen overall pest loads or result in acceptable yields. Readers are reminded that reduced tillage and the use of cover crops provide both positive and negative consequences. The "bottom line" is that certain steps are always justified (identifying pests and beneficial species, minimizing insecticide use, and using selective insecticides); the value of other steps is more difficult to assess.

Conventional Control Methods

Where alternatives to conventional insecticides do not solve insect pest problems, several choices still remain. In situations where crop losses are likely to be minor (pest infestations exceed thresholds only slightly), choosing to do nothing and to accept the loss is a viable alternative. Organic producers may face this option frequently. To minimize such problems as pesticide drift and the unnecessary treatment of uninfested acreage, applicators can use ground application equipment or "spot-treat" only the infested portions of fields or both.

Choosing the "best" conventional insecticide involves evaluating criteria that are too extensive to discuss in detail in this publication. Acute toxicity to humans and wildlife, water solubility, and environmental persistence are three of the important characteristics that should be considered; effectiveness against target pests is another. Although no reference identifies the single best insecticide for a given pest control problem, this annually revised *Handbook* presents information on pesticide toxicities. Publications by Bicki (1988) and Becker et al. (1989) provide additional information on pesticides in the environment.

Summary

The majority of the field crop acreage in Illinois is not treated with an insecticide on an annual basis. Nevertheless, opportunities exist to reduce the use of broad-spectrum insecticides without reducing crop yields. Rotating crops for corn rootworm control and following Hessian fly-free seeding dates for winter wheat are two examples of effective, nonchemical pest management practices. Practices such as the use of reduced tillage and cover crops are likely to produce mixed results in terms of pest management; populations of some pests will increase while others decrease. Regardless of the effects of crop production practices, monitoring pest populations and treating only when necessary still represent important steps in optimizing the use of insecticides. Where pest problems occur, pesticides such as *Bt* offer clear advantages to the environment and to human health. Where no "alternative" methods of pest management exist, procedures as simple as spot spraying offer obvious advantages over spraying entire fields when only small portions are infested. Overall, using the least toxic and least disruptive approaches to pest management can help to ensure a positive future for Midwest agriculture.

Don Graffis (University of Illinois), Paige Taylor (USDA, West Lafayette, Indiana), and Marcos Kogan (Illinois Natural History Survey) contributed information for this chapter. The authors thank Audrey Hodgins of the Illinois Natural History Survey for editorial contributions. Funding to develop this chapter was provided in part by a grant from the Illinois Department of Energy and Natural Resources (ENR Project No. IP13) and by the Cooperative Extension Service, University of Illinois.

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Available from Additional Resources:

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3 Weed Control for Corn, Soybeans, and Sorghum

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This guide is based on the results of research conducted by the University of Illinois Agricultural Experiment Station, other experiment stations, and the U.S. Department of Agriculture (USDA). The soils, crops, and weed problems of Illinois have been given primary consideration.

The user should have an understanding of cultural and mechanical weed control. These practices change little from year to year, so this text will focus on making practical, economical, and environmentally sound decisions regarding herbicide use.

Most of the suggestions in this guide are intended primarily for ground applications. For aerial applications, such factors as amount of water and adjuvant may differ.

Precautions

The benefits of chemical weed control must be weighed against the potential risks to crops, people, and the environment. Discriminate use should minimize exposure of humans and livestock, as well as desirable plants. Risks can be reduced by observing current label precautions.

Current Label

Precautions and directions for use may change. Herbicides classified as restricted-use pesticides (RUP) must be applied only by certified applicators (Table 1). Their use may be restricted because of toxicity or environmental hazards. Toxicity is indicated by the signal word on the label.

Signal Word

Heed the accompanying precautions. The signal word for herbicides discussed in this guide is given in Table 1. "Danger-Poison" and "Danger" indicate high toxicity hazards, while "Warning" indicates moderate toxicity. Always use protective apparel and equipment for handling and application as specified on the label. Be sure that persons or animals not directly involved in the operation are not in the area. Use special precautions near residential areas.

Environmental Hazards

Groundwater advisories (Table 1) must be observed, especially on sandy soils with a high water table. The threat of toxicity to fish and wildlife is indicated under "Environmental Hazards" on the label. Hazards to endangered species may be indicated.

Proper Herbicide Use

Apply only to approved crops at the proper rate and time. Illegal residues can result from overapplication or wrong timing. Observe the recommended harvesting or grazing intervals after treatment.

Proper Equipment Use

Make sure that spray tanks are clean and free of other pesticide residues. Many herbicide labels provide cleaning suggestions, which are particularly important when spraying different crops with the same sprayer and using postemergence herbicides. Correctly calibrate and adjust the sprayer before adding the herbicide to the tank.

Proper Drift Precautions

Spray only on calm days or when the wind is very light. Make sure the wind is not moving toward areas of human activity, susceptible crops, or ornamental plants. Nearby residential areas or fields of edible, horticultural crops deserve particular attention. *Use special precautions with Gramoxone Extra, Command, dicamba, and 2,4-D,* as symptoms of injury have occurred far from the application site.

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

Precautions to Protect the Crop

Avoid applying a herbicide to crops under stress or predisposed to injury. Crop sensitivity varies with size of the crop and climatic conditions, as well as previous injury from plant diseases, insects, or chemicals.

Proper Recropping Interval

Failure to observe the proper recropping intervals may result in carryover injury to the next crop. Soil texture, organic matter, and pH may affect herbicide persistence. Atrazine used in corn or milo can carry over and injure susceptible follow crops. Many soybean herbicides have special recropping restrictions. Check Table 2 and current labels for recropping restrictions.

Proper Storage

Promptly return unused herbicides to a safe storage place. Pesticides should be stored in their original, labeled containers in a secure place away from unauthorized people (particularly children) or livestock and their food or feed.

Proper Container Disposal

Liquid containers should be pressure- or triple-rinsed. Properly rinsed containers can be handled at approved sanitary landfills or possibly recycled. Haul paper containers to a sanitary landfill or burn them in an approved manner. If possible, use mini-bulk returnable containers.

Check Current Labels

This guide has been developed to help you use herbicides effectively and safely. Because no guide can remove all of the risk involved, however, the University of Illinois and its employees assume no responsibility for the results of using herbicides, even if they have been used according to the suggestions, recommendations, or directions of the manufacturer or any governmental agency.

Cultural and Mechanical Control

Good cultural practices that aid in weed control include adequate seedbed preparation, adequate fertilization, crop rotation, planting on the proper date, use of the optimum row width, and seeding at the rate required for optimum stands.

Planting in relatively warm soil can help the crop emerge quickly and compete better with weeds. Good weed control during the first 3 to 5 weeks is extremely important for both corn and soybeans. If weed control is adequate during that period, corn and soybeans will usually compete quite well with most of the weeds that begin growing later.

Narrow rows will shade the centers faster and help the crop compete better with the weeds. If herbicides alone cannot give adequate weed control, however, then keep rows wide enough to allow for cultivation.

If a preemergence or preplant herbicide does not appear to be controlling weeds adequately, use the rotary hoe while weeds are still small enough to be controlled. Use the rotary hoe after weed seeds have germinated but before most weeds have emerged. Operate it at 8 to 12 miles per hour, and weight it enough to stir the soil and kill the tiny weeds. Rotary hoeing also aids crop emergence if the soil is crusted.

Row cultivators also should be used while weeds are small. Throwing soil into the row can help smother small weeds. Cultivate shallowly to prevent injury to crop roots.

Herbicides can provide a convenient and economical means of early weed control and allow for delayed and faster cultivation. Furthermore, unless the soil is crusted, it may not be necessary to cultivate some fields if herbicides are controlling weeds adequately.

Herbicide Incorporation

Sutan+, Eradicane, Command, Treflan, and Sonalan are incorporated after application to minimize surface loss from volatilization and/or photodecomposition. Atrazine, Bladex, Lasso, Dual, Prowl, Pursuit, and Scepter may be incorporated to minimize dependence upon timely rainfall or to improve control of certain weed species.

Incorporation should place the herbicide uniformly throughout the top 1 or 2 inches of soil for the best control of small-seeded annual weeds that germinate at shallow depths. Slightly deeper placement may improve the control of certain weeds from deep-germinating seed under relatively dry conditions. Incorporating too deeply, however, tends to dilute the herbicide and may reduce its effectiveness. The field cultivator and tandem disk place most of the herbicide at about one-half the depth of operation. Thus, for most herbicides, the suggested depth of operation is 3 to 4 inches for most tillage tools.

Thorough incorporation with ground-driven implements usually requires two passes. If the first pass sufficiently covers the herbicide to prevent surface loss, the second pass can be delayed until immediately before planting. Single-pass incorporation may be adequate with some herbicides and some equipment, especially if rotary hoeing, cultivation, or subsequent herbicide treatments are used to improve weed control.

For some herbicides, accurate application and uniform distribution can be very important for avoiding carryover problems.

The depth and thoroughness of incorporation depend upon the type of equipment used, the depth and speed of operation, the texture of the soil, and the amount of soil moisture. Field cultivators and tandem disks are commonly used for incorporation; however, disk-chisels and other combination tools are being used in some areas.

Field Cultivators

Field cultivators are frequently used for herbicide incorporation. They should have three or more rows of shanks with an effective shank spacing of no more than 8 to 9 inches (a spacing of 24 to 27 inches on each of three rows). The shanks may be equipped with points or sweeps. Sweeps usually give better incorporation, especially when soil conditions are a little too wet or dry for optimum soil flow and mixing. Sweeps for C-shank cultivators should be at least as wide as the effective shank spacing.

The recommended operating depth for the field cultivator is 3 to 4 inches. It is usually sufficient to operate the field cultivator only deep enough to remove tractor tire depressions. The ground speed should be at least 6 miles per hour. The field cultivator must be operated in a level position so that the back shanks are not operating in untreated soil, which would result in streaked weed control. Two passes are recommended to obtain uniform weed control with most herbicides. However, single-pass incorporation may sometimes be adequate for some herbicides with certain equipment and soil conditions. If single-pass incorporation is preferred, the use of wider sweeps or narrower spacing with a 3- to 5-bar harrow or rolling baskets pulled behind will increase the probability of obtaining adequate weed control.

Tandem Disks

Tandem disk harrows invert the soil and usually place the herbicide deeper in the soil than most other incorporation tools. Tandem disks used for herbicide incorporation should have disk blade diameters of 20 inches or less and blade spacings of 7 to 9 inches. Larger disks are considered primary tillage tools and should not be used for incorporating herbicides. Spherical disk blades give better herbicide mixing than do conical disk blades.

Tandem disks usually place most of the herbicide in the top 50 to 60 percent of the operating depth. For most herbicides, the suggested operating depth is from 3 to 4 inches. Two passes are recommended to obtain uniform mixing with a double disk. A leveling device (harrow or rolling baskets) should be used behind the disk to obtain proper mixing. Recommended ground speeds are usually between 4 and 6 miles per hour. The speed should be sufficient to move the soil the full width of the blade spacing. Lower speeds can result in herbicide streaking.

Combination Tools

Several new tillage tools combine disk gangs, field cultivator shanks, and leveling devices. Many of these combination tools can handle large amounts of surface residue without clogging and yet leave considerable crop residue on the soil surface for erosion control. Results indicate that these combination tools may provide more uniform one-pass incorporation than a disk or field cultivator, but one pass with them is generally no better than two passes with the disk or field cultivator.

Chemical Weed Control

Plan your weed-control program to fit your soils, tillage program, crops, weed problems, and farming operations. Good herbicide performance depends on the weather and on wise selection and application. Your decisions about herbicide use should be based on the nature and seriousness of your weed problems. The herbicide selectivity tables in this guide indicate the susceptibility of our most common weed species to herbicides.

Corn or soybeans may occasionally be injured by some of the herbicides registered for use on these crops. To reduce injury to crops, apply the herbicide uniformly, at the time specified on the label, and at the correct rate. (See the section below titled "Herbicide Rates.") Crop tolerance ratings for various herbicides are also given in the tables in this guide. Unfavorable conditions such as cool, wet weather; delayed crop emergence; deep planting; seedling diseases; soil in poor physical condition; and poor-quality seed may contribute to crop stress and herbicide injury. Hybrids and varieties also vary in their tolerance to herbicides and environmental stress factors. Once injured by a herbicide, plants are prone to disease.

Crop planting intentions for next season must also be considered. Where atrazine or simazine are used, you should not plant spring-seeded small grains, small-seeded legumes and grasses, or vegetables the following year. Be sure that the application of Treflan or similar herbicides for soybeans is uniform and sufficiently early to reduce the risk of injury to wheat or corn following soybeans. Refer to the herbicide label for information about cropping sequence and appropriate intervals to allow between different crops. Table 2 provides a summary of some of the recropping restrictions.

Some herbicides have different formulations and concentrations under the same trade name. *No endorsement of any trade name is implied, nor is discrimination against similar products intended.*

Herbicide Combinations

Herbicide combinations can control more weed species, reduce carryover, or reduce crop injury. Numerous combinations of herbicides are sold as premixes, and some are tank-mixed. Registered tank mixes are shown in the tables. Tank-mixing allows you to adjust the ratio of herbicides to fit local weed and soil conditions, while premixes may overcome some of the compatibility problems found with tank-mixing. When using a tank mix, you must follow restrictions on all products used in the combination.

Problems may occur when mixing emulsifiable concentrate (EC) formulations with wettable powder (W), liquid flowable (L), or dry flowable (DF) formulations. These problems can sometimes be prevented by using proper mixing procedures. If using liquid fertilizers, check compatibility in a small lot before mixing a tankful. Fill tanks at least one-fourth full with water or liquid fertilizer before adding herbicides that are suspended. The addition of compatibility agents may be necessary. Wettable powders, dry flowable, or liquid flowable concentrates should be added to the tank and thoroughly mixed before adding emulsifiable concentrates. Emulsify concentrates by mixing with equal volumes of water before adding them to the tank. Empty and clean spray tanks often enough to prevent accumulation of material on the sides and the bottom of the tank.

The user can apply two treatments of the same herbicide (split application) or can use two different herbicides, provided such uses are registered. The use of one herbicide after another is referred to as a sequential or overlay treatment.

Herbicide Rates

Herbicide rates vary according to the time of application, soil conditions, the tillage system used, and the seriousness of the weed infestation. Rates of individual components within a combination are usually lower than rates for the same herbicides used alone.

The rates for soil-applied herbicides usually vary with the texture of the soil and the amount of organic matter the soil contains. (See Table 5 [corn] and Table 9 [soybeans] for rate per acre for use of preplant and preemergence herbicides on several typical Illinois soils.) For sandy soils, the herbicide label may specify reducing the rate or not to use at all if crop tolerance to the herbicide is marginal. Postemergence rates often vary depending upon the size and species of the weeds and whether or not an adjuvant is specified.

The rates given in this guide are, unless otherwise specified, broadcast rates for the amount of formulated product. If you plan to band or direct herbicides, adjust the amount per crop acre according to the percent of the area actually treated. Herbicides may have several formulations with different concentrations of active ingredient. Be sure to read the label and make necessary adjustments when changing formulations.

Postemergence Herbicide Principles

Postemergence herbicides applied to growing weeds generally have foliar rather than soil action; however, some may have both. The rates and timing of applications are based on weed size and climatic conditions. (See Tables 14, 15, and 17 for examples of rates versus weed sizes for soybean postemergence herbicides.) Weeds can usually be controlled with a lower application rate when they are small and tender. Larger weeds often require a higher herbicide rate. Herbicide penetration and action are usually greater with warm temperature and high relative humidity. Rainfall occurring too soon after application (1 to 8 hours, depending on the herbicide) can cause poor weed control.

Translocated herbicides are most effective at lower spray volumes (5 to 20 gallons per acre), whereas contact herbicides require more complete coverage. Foliar coverage increases as water volume and spray pressure are increased. Spray nozzles that produce small droplets also improve coverage. For contact herbicides, 20 to 40 gallons of water per acre are often recommended for ground application, and a minimum of 5 gallons per acre is recommended for aerial application. Spray pressures of 30 to 60 psi are often suggested with flat-fan or hollow-cone nozzles to produce small droplets and improve canopy penetration. *These small droplets are quite subject to drift.*

The use of an adjuvant such as a surfactant, crop-oil concentrate, or fertilizer solution may be recommended to improve spray coverage and herbicide uptake. These spray additives will usually improve weed control but may increase crop injury. Spray additives may be needed, especially under droughty conditions or on larger weeds.

Crop size limitations may be specified on the label to minimize crop injury and maximize weed control. If weeds are smaller than the crop, basal-directed sprays may minimize crop injury because they place more herbicide on the weeds than on the crop. If the weeds are taller than the crop, rope-wick or sponge-type applicators may be used to place the herbicide on the top of the weeds and minimize contact with the crop. Follow the label directions and precautions for each herbicide.

Conservation Tillage and Weed Control

Conservation tillage allows crop production while it reduces soil erosion by protecting the soil surface with plant residue. Minimum or reduced tillage refers to any tillage system that leaves crop residue on the soil surface. These include primary tillage with chisel plows or disks and the use of field cultivators, disks, or combination tools for secondary tillage. Mulch tillage is reduced tillage that leaves at least 30 percent of the soil surface covered with plant residue.

Ridge tillage and zero tillage are conservation tillage systems with no major tillage prior to planting. In ridge tillage, conditions are often ideal for banding of preemergence herbicides. Cultivation is a part of the system. "No-till" is actually slot tillage for planting with no overall primary tillage. No-till planting conserves moisture, soil, and fuel. It also allows timely planting of soybeans or sorghum after winter wheat harvest.

If tillage before planting is eliminated, undesirable existing vegetation at planting must be controlled with herbicides. The elimination or reduction of herbicide incorporation and row cultivation puts a greater reliance on chemical weed control. Soil conditions must be ideal for single-pass herbicide incorporation to be uniform. Greater emphasis may be placed on preplant or postplant soil-applied herbicides that are not incorporated or on foliar-applied herbicides.

Where primary tillage is minimized, soil residual herbicides applied several weeks before planting may reduce the need for a "knockdown" herbicide. However, early preplant (EPP) application may require additional preemergence or postemergence herbicides or cultivation for satisfactory weed control after planting. See the sections on corn and soybeans under "Preplant Not Incorporated" for more details.

Corn and soybeans are the primary crops in Illinois, and they are often planted in a corn and soybean rotation. Modern equipment allows successful no-till planting in corn or soybean stubble. The use of a disk or chisel plow on corn stubble may still provide adequate crop residue to allow minimum tillage. Herbicides are also available to allow a "total postemergence" weed control program, especially for soybeans.

Soybean stubble is often ideal for zero or minimum tillage. Primary tillage is rarely needed, and the crop residue should not interfere with herbicide distribution. Early preplant application of preemergence herbicides or the use of postemergence herbicides can often provide adequate weed control.

The existing vegetation in corn and soybean stubble is often annual weeds. If the weeds are small, they can often be controlled before planting with herbicides that have both foliar and soil residual activity (Table 3). For corn, these include atrazine or Bladex and their premixes. For soybeans, metribuzin (Sencor or Lexone), linuron (Lorox), and their premixes with chlorimuron (Preview, Canopy, or Lorox Plus), as well as Pursuit can be used. Foliar activity is enhanced with the addition of crop-oil concentrate (COC) or surfactant.

Sod planting requires a different approach. If minimum or zero tillage is to be used in perennial grass or legume sods, *the sod should be controlled prior to planting.* Late control of sod may deplete soil moisture, making crop establishment difficult. Some grass sods may require the use of Roundup *in the fall* when there is adequate foliage and translocation for effective control. Bluegrass or clover may be controlled by atrazine alone or combined with Bladex. Clover sods can be controlled by Roundup, Banvel, or 2,4-D applied in the fall before planting soybeans. Roundup, Banvel, or 2,4-D can be applied in the fall or spring ahead of corn. Alfalfa may be controlled with Banvel or Banvel plus 2,4-D. *Do not plan to take a spring cutting before planting into forage sods.* Regrowth rarely provides sufficient foliage for active herbicide uptake to kill the sod prior to planting corn.

Winter cover crops of wheat or rye can be controlled by Roundup prior to planting corn or soybeans, or Gramoxone plus atrazine may be used prior to planting corn. A winter cover crop of hairy vetch can be controlled with 2,4-D or Banvel before or after planting corn.

Annual vegetation over 2 to 3 inches tall at planting time may require a burndown or translocated herbicide. Gramoxone, Roundup, or Bronco can be used with most preemergence herbicides to control vegetation that is already present.

Gramoxone Extra (paraquat) can be used to control existing vegetation before planting. Gramoxone Extra **2.5S** is used at 1.5 to 3 pints per acre. It should be applied with a nonionic surfactant or crop-oil concentrate in at least 20 gallons of spray per acre. The addition of a photosynthetic inhibitor herbicide can improve control of smartweed, giant ragweed, and "marestail." *Gramoxone Extra is a restricted-use pesticide.*

Roundup (glyphosate) can be used at 3 to 8 pints per acre to control existing vegetation prior to planting. Roundup at the higher rates can translocate to the roots to control some perennials. Spray volume per acre should be 20 to 40 gallons. Small annual weeds can be controlled with 0.75 to 1 pint of Roundup in 5 to 10 gallons of water per acre plus 0.5 percent nonionic surfactant. Micro Tech or Bullet should not be mixed with Roundup unless ammonium sulfate is added at 17 pounds per 100 gallons of water. The ammonium sulfate should be mixed with water first and then the Micro Tech or Bullet added before adding Roundup.

Bronco (glyphosate plus alachlor) contains the equivalent of 2.6 quarts of Lasso EC and 1.4 quarts of Roundup per gallon. Bronco is used at 6 to 10 pints per acre applied in 10 to 30 gallons of water. Application can also be made in urea-ammonium nitrate (UAN) solutions if annual weeds are less than 6 inches tall. *Bronco is a restricted-use pesticide.*

Banvel (dicamba) may be used in the fall or spring before planting corn or only in the fall before planting soybeans. Banvel can control annual and some perennial broadleaf plants including clovers and alfalfa. A combination of Banvel plus 2,4-D can often control more weeds at lower cost.

2,4-D can be used in the fall or spring before planting corn or possibly before no-till soybeans to control broadleaf weeds. *See current 2,4-D label.*

Herbicides for Corn

Herbicides mentioned in this section are registered for use on field corn. Some are also registered for silage corn. See Table 4 for registered combinations. Herbicide suggestions for sweet corn and popcorn may be found in Chapter 11, "Weed Control for Commercial Vegetable Crop." Growers producing hybrid seed corn should check with the contracting company or the producer of inbred seed about tolerance of the parent lines. Rates for preplant and preemergence herbicides to use on several typical Illinois soils are given in Table 5. See Tables 6 and 7 for weeds controlled by the herbicides used in corn.

Preplant Not Incorporated (Corn)

Early preplant herbicide application is used in no-till programs to minimize existing vegetation problems at planting and reduce the need for a knockdown herbicide. Atrazine, Bladex, and Extrazine have both foliar and soil activity so they may control small annual weeds prior to planting corn, especially if a nonionic surfactant or crop-oil concentrate is added to the spray mix. However, if weeds over 2 to 3 inches tall are present, add Gramoxone Extra, Roundup, 2,4-D ester, Banvel, or Marksman. See Table 3 for weeds controlled by these herbicides.

Atrazine, Bicep, Bullet, Dual, Cycle, or Micro Tech can be used within 30 days of corn planting as a single full-rate application or within 45 days if application is split before planting and at planting. *Atrazine, Bicep, Bullet, Cycle, and Micro Tech are restricted-use pesticides.*

Bladex or Extrazine II can be applied 15 to 30 days before planting corn. Apply before weeds germinate or seedlings are more than 3 inches tall. *Bladex and Extrazine II are restricted-use pesticides.*

Banvel or Marksman can be applied before or at planting. On medium- or fine-textured soils with at least 2 percent organic matter, use 1 pint of Banvel or 3.5 pints of Marksman per acre. On other soils *under no-till only,* use 0.5 pint of Banvel or 2 pints of Marksman per acre. To control alfalfa or clover sod, apply after 4 to 6 inches of regrowth. 2,4-D can be added to improve control of dandelions or plantains. *Marksman is a restricted-use pesticide.*

2,4-D can be used to control existing vegetation before planting reduced-tillage corn. Some preplant tank-mixes allow 1 to 2 pints of 2,4-D LV ester per acre. See the specific label for the instructions.

Buctril + Atrazine (tank-mix or premix) can control some existing vegetation before planting field corn. *Buctril + Atrazine is a restricted-use pesticide.*

Roundup or Gramoxone Extra has no residual control but can be tank-mixed with most other preplant herbicides to control existing vegetation before planting corn. See the conservation tillage section in this chapter for more information. *Gramoxone Extra is a restricted-use pesticide.*

Preplant-Incorporated Herbicides (Corn)

Sutan+ (butylate) or Eradicane or Eradicane Extra (EPTC) require incorporation because they are volatile. Apply within 2 weeks of the expected planting date. If possible, application and incorporation should be done at the same time. *Do not delay incorporation more than 4 hours.*

Sutan+ and Eradicane control annual grass weeds and are used at 4-3/4 to 7-1/3 pints per acre. The rate for Eradicane Extra 6E is 5-1/3 to 8 pints per acre. Use the higher rates for heavy weed infestations or to suppress certain problem weeds.

Sutan+ or Eradicane may be tank-mixed with atrazine, Bladex, or Extrazine II to improve broadleaf control. **Sutazine,** a premix of butylate (Sutan+) and atrazine, is used at 5.25 to 10.5 pints 6ME or 16.7 to 22.7 pounds 18-6G per acre. *Sutazine is a restricted-use pesticide.*

Preplant or Preemergence Herbicides (Corn)

AAtrex or Atrazine (atrazine) or Princep (simazine) are often incorporated before planting because of low solubility. Atrazine alone is used at 4 pints 4L or 2.2 pounds 90DF per acre. The rate is 2 to 3 pints

4L or 1.1 to 1.8 pounds 90DF per acre for broadleaf control in tank mixes with other herbicides to control grass weeds. *All products containing atrazine are restricted-use pesticides because of the risk of groundwater and surface contamination.*

Required Changes in Atrazine Use

Surface water concerns bring new atrazine restrictions involving rate limits and buffer zones to help protect surface water. Maximum single application is 1.6 to 2 pounds atrazine active ingredient (a.i.) per acre and a total of 2.5 pounds per acre per year. The 1.6-pound rate is for highly erodible land (HEL) with less than 30 percent crop residue.

Required buffer zones (set-backs) are 66 feet between application sites and "points where field surface water can enter streams and rivers" and 200 feet from lakes and reservoirs. On HEL, the 66-foot buffer zone must be planted in crop or seeded in grass. No mixing or loading of atrazine is allowed within 50 feet of streams, rivers, lakes, or reservoirs.

The use of premixes containing atrazine makes calculations of total atrazine use difficult, especially if both soil-applied and postemergence premixes are used. Pounds of active ingredient (a.i.) of atrazine per gallon or pint for liquid premix corn herbicides containing atrazine are listed below:

	Lb atrazine a.i.	
Premix and form	gallon	pint
Atrazine 4L	4.00	0.500
Bicep 6L	2.67	0.333
Bicep Lite 5L	1.67	0.209
Buctril + Atrazine 3L	2.00	0.250
Bullet 4L	1.50	0.189
Extrazine II 4L	1.00	0.125
Laddok 3.3L	1.67	0.209
Lariat 4L	1.50	0.189
Marksman 3.2L	2.10	0.263
Sutazine 6L	1.20	0.150

Example: If you apply 4.8 pints of Bicep (1.602 lb atrazine a.i.) and 3.5 pints of Marksman (0.920 lb atrazine a.i.), you have applied a total of 2.522 pounds of atrazine a.i. per acre, slightly over the 2.5 pounds allowed.

Atrazine and simazine can persist to injure follow crops. The risk of carryover is greater after a cool, dry season and on soils with a pH greater than 7.3. Soybeans planted the next year may show injury from atrazine carryover. If you apply atrazine after June 10, plant only corn or sorghum the next year. *Do not plant small grains, clovers, alfalfa, or vegetables in the fall or the next spring after using atrazine.*

Bladex (cyanazine) controls most annual grass weeds but is weaker than atrazine on some broadleaf weeds. Bladex has shorter persistence than atrazine, but atrazine is less likely to injure corn. **Extrazine II** is a 3:1 premix of cyanazine (Bladex) and atrazine used at rates and times similar to those of Bladex.

Select rates of Bladex or Extrazine accurately on the basis of soil texture and organic matter content to reduce the possibility of corn injury (see Table 5). Used alone, Bladex rates are 1.3 to 5.3 pounds of 90DF or 2-1/2 to 9-1/2 pints of 4L per acre, whereas Extrazine rates are 1.4 to 5.8 pounds 90DF or 2-1/2 to 10-1/2 pints 4L per acre. They may be tank-mixed at reduced rates with "grass" herbicides (Table 4) for broadleaf weed control. *Bladex and Extrazine II are restricted-use pesticides.*

Cycle 4L, a 1:1 premix of metolachlor (Dual) and cyanazine (Bladex), can be applied up to 14 days prior to planting and incorporated or used preemergence after planting. The rate is 5 to 9 pints per acre. *Cycle is a restricted-use pesticide.*

Lasso (alachlor) or Dual (metolachlor) primarily controls annual grasses and some small-seeded broadleaf weeds (Tables 6 and 7). To improve broadleaf control, they can be combined with atrazine or Bladex. Dual may be applied and shallowly incorporated within 45 days before planting, or it may be used after planting. The rates are 1-1/2 to 4 pints of Dual 8E or 6 to 16 pounds of Dual 25G per acre.

Alachlor may be applied and shallowly incorporated within 30 days of planting or immediately after planting corn. Use 4 to 8 pints per acre of Lasso 4E or Micro Tech 4ME or equivalent rates of Lasso 15G or Partner 65WDG. Arena, Judge, Stall, Saddle, and Confidence are distributor brands of alachlor. **Cropstar 20G** is intended for mixing and application with dry fertilizer. **Partner and Micro Tech** are encapsulated formulations of alachlor that may have an advantage over Lasso 4E for reduced or no-till systems. *Products containing alachlor are restricted-use pesticides.*

Lasso or Dual plus atrazine may be applied preplant or after planting until corn is 5 inches tall and grass weeds have not passed the two-leaf stage. *Do not use liquid fertilizer as the carrier after corn emergence.*

Bicep 6L and Bicep Lite 5L are 5:4 and 2:1 premixes, respectively, of metolachlor (Dual) plus atrazine used at 3 to 6 pints per acre. **Bullet 4L and Lariat 4L** are 5:3 premixes of alachlor (Micro Tech and Lasso, respectively) plus atrazine used at 5 to 10.5 pints per acre. *Bicep, Bicep Lite, Bullet, and Lariat are restricted-use pesticides.*

Pursuit (imazethapyr) can be used early preplant, preplant incorporated, or preemergence, or early postemergence *on Pursuit-resistant or -tolerant field corn hybrids. Do not use Counter 15G at planting if Pursuit-tolerant hybrids are used.* The Pursuit rate is 4 fluid ounces (0.25 pint) per acre alone or mixed with grass herbicides (see Table 4) to improve grass control.

Preemergence Herbicides (Corn)

Marksman (dicamba + atrazine) or Banvel (dicamba) can be applied after planting corn on medium- to fine-textured soils containing at least 2 percent organic matter. The rate is 3.5 pints of Marksman or 1 pint of Banvel. On other soils, *if the corn is no-till,* Marksman can be applied at 2 pints and Banvel at 0.5 pints per acre. Banvel or Marksman can be tank-mixed with other herbicides (Table 4) and applied preemergence or early postemergence. *Do not incorporate Marksman or Banvel. Marksman is a restricted-use pesticide.*

Prowl (pendimethalin) can be used preemergence after planting corn, *but do not incorporate.* Corn should be planted at least 1.5 inches deep. The Prowl 3.3E rate per acre is 1.8 to 4.8 pints alone or 1.8 to 3.6 pints in most tank-mix combinations. Most Prowl tank mixes can also be applied early postemergence, but see the label for corn size limitations.

Postemergence Herbicides (Corn)

Several preemergence herbicide tank-mixes or premixes may also be applied early postemergence to corn (Table 4). Most require the grass weeds to be less than 1.5 to 2 inches tall for effective control. *Do not use liquid fertilizer as the carrier when applying postemergence herbicides.* Some herbicides will control grass weeds; others will control broadleaf weeds (see Tables 6 and 7). Several combinations of postemergence herbicides are registered (see Table 8).

Postemergence Grass Control in Corn

Accent, Beacon, atrazine, Bladex, or Extrazine II can be used to control some grass weeds (see Table 6). Atrazine, Bladex, or Extrazine II must be applied before annual grass weeds are over 1.5 inches tall. These herbicides also control several broadleaf weeds.

Accent and Beacon are used for postemergence grass control in field corn. Both can control shattercane and johnsongrass, but Accent is better for giant foxtail and fall panicum control. Check label restrictions on Counter use before applying Accent or Beacon and for tank mixing or sequencing with other herbicides. Accent or Beacon are considered rainfast within 4 to 6 hours.

Accent 75DF (nicosulfuron) can be applied broadcast or with drop nozzles to field corn up to 24 inches tall (free standing). For corn 24 to 36 inches tall, use drop nozzles. Do not use Accent on corn past the 36-inch or ten-leaf collar stage. The rate is 2/3 ounce of product per acre in a minimum of ten gallons of water per acre. A second application may be made 14 to 28 days later if needed.

Weed height limitations when using Accent are 2 to 4 inches for giant foxtail and fall panicum, 4 to 12 inches for shattercane, 8 to 18 inches for rhizome johnsongrass, and 4 to 10 inches for quackgrass.

Accent can be tank-mixed with atrazine, Buctril, Buctril + Atrazine, Banvel, or Marksman, but observe corn height limitations for the tank-mix partner. For Accent plus atrazine, crop-oil concentrate is used. For the other tank mixes, use only a nonionic surfactant. Do not tank-mix Accent with Bladex, Basagran, Laddok, or 2,4-D. Do not apply Accent to corn previously treated (within 7 days) with foliar-applied organophosphate insecticides or with Basagran or Laddok. Do not apply Basagran or Laddok within 3 days after applying Accent.

Beacon 75DF (primisulfuron) can be applied to corn that is 4 to 20 inches tall. A 1.52-ounce packet treats 2 acres. Split applications (50%/50% or 75%/25% will provide better control of johnsongrass and quackgrass, but the second application should be made before tassel emergence. Weed height limitations for Beacon are 4 to 12 inches for shattercane, 8 to 16 inches for rhizome johnsongrass, 4 to 8 inches for quackgrass, and less than 2 inches for fall panicum. Beacon can also control several broadleaf weeds (see Table 7).

With Beacon, use nonionic surfactant (NIS) at 1 quart per 100 gallons of spray or crop-oil concentrate (COC) at 1 to 4 pints per acre; UAN can also be added, up to 1 gallon per acre. If Beacon is tank-mixed with Buctril, Banvel, or 2,4-D, use nonionic surfactant and not crop-oil concentrate or UAN. Use a minumum of 10 gallons of spray per acre.

If Beacon is to be used, do not use Counter at or before planting corn. Some effect on corn may be noted if other organophosphate insecticides are used at planting. Do not apply any organophosphate insecticide within 10 days before or after Beacon application. Observe label restrictions for preharvest intervals and recropping.

Pursuit (imazethapyr) can be used postemergence *on Pursuit-resistant or -tolerant field corn hybrids. Do not use Counter 15G at planting if Pursuit-tolerant hybrids* *are used.* The rate is 4 fluid ounces per acre of Pursuit alone or mixed with atrazine or Buctril. Postemergence, Pursuit requires the addition of a surfactant or crop-oil concentrate *and* a fertilizer adjuvant (see label). Pursuit will be used postemergence primarily to control shattercane and giant foxtail, where it is price competitive with Beacon and Accent. *Do not tank-mix Pursuit with Accent or Beacon.*

Atrazine must be applied before corn is 12 inches tall. Use 2.2 pounds 90DF or 4 pints 4L plus 1 quart crop-oil concentrate (COC) per acre to control annual grass weeds less than 1.5 inches tall. Many annual broadleaf weeds up to 4 inches tall are controlled with 1.3 pounds 90DF or 2.4 pints 4L plus 1 quart of COC per acre. *Do not apply more than a total of 2.5 pounds atrazine (a.i.) per acre per year.*

Atrazine plus COC may injure corn that has been under stress from prolonged cold, wet weather or other factors. *Do not add 2,4-D with the atrazine plus COC.* Mix the atrazine with water first and then add the COC. If atrazine is applied after June 10, plant only corn or sorghum the next year. *Atrazine is a restricted-use pesticide.*

Bladex (cyanazine) or Extrazine II (cyanazine + atrazine) may be applied until the five-leaf stage in field corn and before grass weeds exceed 1.5 inches in height. The rate per acre is 1.1 to 2.2 pounds 90DF or 2.2 to 4 pints 4L. Use 4L formulations only under warm, dry, sunny conditions of low humidity. Do not apply Bladex or Extrazine II to corn that is stressed or growing under cold, wet weather. Under dry, arid conditions, a surfactant or vegetable oil may be added to 90DF (not 4L) formulations. Do not use petroleum-based crop oils or apply with liquid fertilizer. *Extrazine II and Bladex are restricted-use pesticides.*

Postemergence Broadleaf Control (Corn)

Banvel, Stinger, and 2,4-D are plant hormone herbicides that control broadleaf weeds in corn (see Table 7). Observe drift precautions with these herbicides. Buctril, Buctril + Atrazine, and Laddok are contact herbicides, so good spray coverage is essential.

Banvel (dicamba) or Marksman (dicamba + atrazine) may be applied from spike to five-leaf or 8-inch stage in corn. Use 1 pint of Banvel or 3-1/2 pints of Marksman per acre except on coarse-textured soils, when the rate to use is 1/2 pint of Banvel or 2 pints of Marksman per acre. Banvel may also be applied at 1/2 pint to corn that is 8 to 36 inches tall or 15 days before tassels emerge, whichever comes first. Use drop nozzles on corn over 8 inches tall to reduce the risk of corn injury, improve spray coverage, and reduce drift. *Do not apply Banvel to corn over 24 inches tall or if nearby soybeans are over 10 inches tall or have begun to bloom.*

Observe all label precautions to minimize the risk of Banvel or Marksman drifting to nearby susceptible crop or ornamental plants. The Banvel label calls for directed application if applied with 2,4-D.

Stinger (clopyralid) can be used on field corn up to 24 inches in height. The rate per acre is 1/4 to 1/2 pint for ragweed, cocklebur, sunflower, Jerusalem artichoke, and jimsonweed up to the five-leaf stage, and 1/3 to 2/3 pint for Canada thistle. The interval before planting soybeans is 12 months after application.

2,4-D amine or ester can be used from emergence to tasseling of corn. Apply with drop nozzles if corn is more than 8 inches tall. The rate is 1/3 to 1/2 pint of 2,4-D ester or 1 pint of 2,4-D amine if the acid equivalent is 3.8 pounds per gallon. 2,4-D ester can vaporize and injure susceptible plants nearby if temperatures exceed 85°F. Spray particles of either 2,4-D ester or amine can drift and cause injury to susceptible plants.

Corn is often brittle for 1 to 2 weeks after application of 2,4-D and may be susceptible to stalk breakage from high winds or cultivation. Other symptoms of 2,4-D injury are stalk lodging, abnormal brace roots, and failure of leaves to unroll. Corn hybrids differ in their sensitivity to 2,4-D. High humidity and temperature increase the potential for 2,4-D injury to corn.

Buctril (bromoxynil) is used at 1 pint per acre after emergence or up to 1.5 pints per acre after the four-leaf stage of corn up to tassel emergence, but while weeds are in the three- to eight-leaf stage. Larger pigweed and velvetleaf may require the higher rate or a combination with atrazine.

Buctril + Atrazine 3L is used at 1.5 to 3 pints per acre, or Buctril can be tank-mixed with 1 to 2.4 pints atrazine 4L or 0.6 to 1.3 pounds atrazine 90DF. At the higher rate, do not apply until the four-leaf stage of corn. Do not apply to corn over 12 inches tall. Surfactants or crop-oil concentrate can be added, but the potential for corn injury increases. *Buctril + Atrazine is a restricted-use pesticide.*

Laddok (bentazon + atrazine) is used at 2 to 3-1/2 pints per acre until corn is 12 inches tall. Always add 1 gallon of UAN or 1 quart of crop-oil concentrate (COC) or Dash per acre for ground application. Use the COC or Dash for suppression of Canada thistle or yellow nutsedge. *Laddok is a restricted-use pesticide.*

Postemergence Soil-Applied Herbicides (Corn)

Some herbicides that are normally applied to the soil may be used postemergence in corn to back up herbicides that had been applied earlier and to keep late-emerging weeds from becoming problems. Drop nozzles should be used if corn foliage prevents uniform application to the soil.

Prowl (pendimethalin) or Treflan (trifluralin) may be applied after *field corn* is 4 inches tall (for Prowl) or from the two-leaf stage (for Treflan) up to last cultivation. Prowl or Treflan plus atrazine can be tank-mixed, but do not apply after corn is 12 inches tall. Apply the herbicide and then incorporate with a sweep or rolling cultivator. Prowl may not require incorporation if rainfall occurs soon after application. These treatments are used to help control late-emerging grasses such as shattercane, wild proso millet, fall panicum, or woolly cupgrass. *Do not use Prowl in corn more than once per crop season.* Observe recropping restrictions, especially for wheat.

Dual (metolachlor) plus atrazine as a tank mix or premix (Bicep) can be used postemergence to control weeds in corn up to 12 inches high, especially in seed corn, where late-emerging weeds become problems. See the current label for rate and timing restrictions.

Directed Postemergence Herbicides for Emergencies (Corn)

Directed (not over-the-top) sprays of Lorox, Poast, or Gramoxone Extra can be used for emergencies if weed and crop size limits are met. Early cultivation may allow for the proper height differential between the crop and weeds. Direct the spray to the base of the corn plants to minimize injury to the corn while covering the weeds as much as possible. *Adjust rates for banded application.*

Lorox (linuron) may be used in field corn at least 15 inches tall (freestanding) but before weeds are 5 inches tall. Use Lorox at 1.25 to 3 pounds 50DF or at 1-1/4 to 3 pints 4L per acre, depending upon the weed size and soil type. Add 1 pint of surfactant per 25 gallons of spray.

Gramoxone Extra (paraquat) may be applied after corn is 10 inches tall as a directed spray no higher than the lower 3 inches of cornstalks. Use 12.8 fluid ounces of Gramoxone Extra in 20 to 40 gallons of water per acre. A nonionic surfactant or crop-oil concentrate should be added. A tank mix with atrazine can increase broadleaf control. Observe current label precautions. *Gramoxone Extra is a restricted-use pesticide.*

Poast (sethoxydim) is labeled for use to control some grass weeds in corn. Corn should be at least 30 inches tall with most weed species not over 8 inches. Appropriate equipment should be used so spray is no more than 10 inches high on the cornstalk. Crop-oil concentrate should be added. *Do not add Dash or any fertilizer additive. Do not use Poast Plus.* For broadleaf weeds, 2,4-D may be added with appropriate precautions. Considerable care should be used with this treatment to reduce risk of corn injury.

Corn Preharvest Treatment

Some labels allow preharvest use of 2,4-D after the hard-dough to dent stage of corn to control or suppress broadleaf weeds that may interfere with harvest. Do not use the corn for forage or fodder for 7 days after treatment.

Herbicides for Sorghum

Atrazine, Dual, Banvel, Bicep, 2,4-D, and Marksman are registered for use in grain or "forage" sorghums. Several other corn herbicides can also be used in grain sorghum or milo, although the application rates may be lower. Check the labels for the relevant information.

Gramoxone Extra (paraquat) or Roundup (glyphosate) can be used to control existing vegetation before planting grain sorghum in reduced-tillage systems. **Bronco (glyphosate + alachlor)** can also be used if the seed is treated with Screen. *Gramoxone Extra and Bronco are restricted-use pesticides.*

Atrazine may be applied to medium-textured soils with more than 1 percent organic matter, but the rates are lower than for corn. Atrazine can also be applied postemergence at 4 pints 4L per acre without crop-oil concentrate (COC) or at 2.4 pints per acre with COC for broadleaf control only. Use equivalent rates of atrazine 90DF. *Atrazine is a restricted-use pesticide.*

Ramrod (propachlor) alone or with atrazine or Bladex can be used only preemergence in grain sorghum. Do not graze or feed forage to dairy animals.

Lasso (alachlor) or Lariat (alachlor + atrazine) can be used if grain sorghum seed is treated with Screen. Micro Tech and Bullet are not registered for use in grain sorghum. *Lasso and Lariat are restricted-use pesticides.*

Dual (metolachlor), Bicep (metolachlor + atrazine), or Cycle (metolachlor + cyanazine) can be used if grain sorghum seed has been treated with Concep II. *Bicep and Cycle are restricted-use pesticides.*

2,4-D may be applied for broadleaf control in sorghum that is 4 to 24 inches tall. Use drop nozzles if sorghum is taller than 8 inches.

Banvel (dicamba) or Marksman (dicamba + atrazine) can be applied to grain sorghum after the two-leaf stage. Marksman can be applied at 1-1/2 to 2 pints per acre until sorghum has five leaves or is 8 inches tall; Banvel can be applied at 0.5 pint per acre to sorghum up to 15 inches tall. Do not graze or feed treated forage to animals before the mature grain stage. *Marksman is a restricted-use pesticide.*

Laddok (bentazon + atrazine) can be used postemergence to control broadleaf weeds in grain or forage sorghum if applied before the crop is 12 inches tall. *Laddok is a restricted-use pesticide.*

Buctril (bromoxynil) applied alone can be used from the three-leaf to boot stage, whereas Buctril that has been tank-mixed or premixed with atrazine can only be applied to grain sorghum up to 12 inches in height.

Roundup (glyphosate) may be applied as a spot treatment in grain sorghum prior to heading.

Herbicides for Soybeans

Consider the kinds of weeds expected when you plan a herbicide program for soybeans. The herbicide selectivity Tables 11, 12, and 13 list herbicides and their relative weed control ratings for various weeds.

Although soybeans may be injured by some herbicides, they usually outgrow early injury with little or no effect on yield if stands have not been significantly reduced. Significant yield decreases can result when injury occurs during the bloom to pod-fill stages. Excessively shallow planting can increase the risk of injury from some herbicides. Accurate rate selection for soil type is essential for herbicides containing metribuzin (Canopy, Lexone, Preview, Salute, Sencor, or Turbo) or linuron (Linex, Lorox, or Lorox Plus) (see Table 8). Do not apply these herbicides after soybeans begin to emerge, or severe injury can result. Always follow label instructions. Rates per acre for preplant or preemergence herbicides for typical Illinois soils are given in Table 9. See Table 10 for some preplant and preemergence tank-mix combinations.

Preplant Herbicides (Soybeans)

Early preplant herbicide application is used in minimum tillage programs to minimize existing vegetation problems at planting and reduce the need for a knockdown herbicide. Broadleaf herbicides used for early preplant application in soybeans have both foliar and soil activity (see Table 3), so they may control small annual weeds prior to planting, especially if a nonionic surfactant or crop-oil concentrate is added to the spray mix. However, if weeds are over 1 to 2 inches tall, add either Gramoxone Extra, Roundup, or Bronco to the spray mix within label guidelines to control existing vegetation. (See the section on "Conservation Tillage and Weed Control.")

Dual can be applied up to 30 days prior to planting or as a split application within 45 days of planting soybeans. The split application rate is a full rate with two-thirds applied preplant and one-third at planting.

Micro Tech or Partner can be applied early preplant north of Interstate 64. A full rate can be applied up to 30 days before planting soybeans, except on sandy soils where a full rate can be applied no more than two weeks preplant. A split of 60 percent of full rate can be applied up to 45 days preplant with the other 40 percent applied at planting.

Canopy, Lorox Plus, or Preview can be applied early preplant up to 30 days before planting soybeans. However, if applied with Dual, this is reduced to 14 days and with Lasso, to 7 days.

Prowl may be applied up to 60 days before planting soybeans. It should be incorporated if rainfall does not occur within 14 days.

Sencor plus Lasso or Dual may be applied up to 30 days before planting soybeans if applied as a split preplant and at-planting application. **Turbo** is a premix of Sencor and Dual.

Command may be applied early preplant in fields under conservation tillage practices. The rate is 1.5 to 2 pints per acre. *Applications must be made prior to field green-up and in Illinois before: April 1 south of I-70 or April 10 north of I-70.* Field green-up means *before* nearby trees and shrubs are showing green leaf tissue (broken dormancy) and *when* summer annual weeds are emerging at the site. Check a current federal label for drift and setback restrictions from critical housing or agricultural areas.

Pursuit or Pursuit Plus can be applied up to 45 days before planting soybeans. However, if sufficient rain does not occur before planting, then mechanical incorporation is required.

Scepter, or Squadron can be surface-applied up to 30 days before planting soybeans.

Roundup may be used preplant in soybeans to control small annual weeds. The rate is 0.75 to 1 pint per acre in 5 to 20 gallons of water with the addition of a nonionic surfactant.

Poast Plus can be used at 0.75 pint per acre before planting soybeans to control small annual grasses. Always add crop-oil concentrate or Dash with Poast Plus.

2,4-D application prior to planting soybeans *may have a conditional label in 1993.* 2,4-D is used to control horseweed (marestail), prickly lettuce, and dandelions, but it can also help suppress or control alfalfa, red clover, or hairy vetch. If 1 pint (3.8 lb a.e./gal) is used, apply low volatile ester (LVE) not less than 7 days, or amine salt not less than 15 days, before planting soybeans. If 2 pints (amine or ester) are used, do not plant soybeans for 30 days after application. Plant soybeans at least 1.5 to 2 inches deep and be sure the planted seed is completely covered. Injury is likely on sandy soils with less than 1 percent organic matter. Check current 2,4-D label.

Butyrac 200 (2,4-DB) may be used alone or in combination with Roundup or Gramoxone Extra preplant through preemergence for soybeans. For no-till or reduced tillage systems, 2,4-DB can help to control such weeds as emerged annual morningglories, cocklebur, and marestail (horseweed). The application rate of Butyrac 200 is 0.7 to 0.9 pint per acre.

Soil-Applied "Grass" Herbicides (Soybeans)

Treflan, Sonalan, and Command are soil-applied herbicides for grass control which require mechanical incorporation, whereas Prowl, Lasso, Micro Tech, and Dual can be used preemergence or preplant-incorporated. Incorporation improves herbicide performance if rainfall is limited. For more information, see the section titled "Herbicide Incorporation" and Tables 11 and 12 for the weeds controlled.

Treflan, Sonalan, and Prowl are dinitroaniline (DNA) herbicides that control annual grasses, pigweed, and lambsquarters. Control of additional broadleaf weeds requires combinations or sequential treatments with other herbicides.

Soybeans are sometimes injured by DNA herbicides. Symptoms are stunting, swollen hypocotyls, and short, swollen lateral roots. Usually, such injuries are not serious. If incorporation is too shallow or Prowl is applied to the soil surface, soybean stems may be calloused and brittle, leading to lodging or stem breakage.

DNA herbicides can sometimes injure rotational crops of corn or sorghum. Symptoms appear as reduced stands and stunted, purple plants with poor root systems. Under good growing conditions, corn typically recovers from this early season injury. Accurate, uniform incorporation is needed to minimize potential carryover.

Treflan, Tri-4, or Trific (trifluralin) may be applied alone anytime in the spring prior to planting. However, tank mixes may specify application closer to soybean planting. Incorporate trifluralin within 24 hours after application or within 8 hours if the soil is warm and moist. The rate per acre is 1 to 2 pints of 4E or equivalent rates of Treflan Pro-5, 10G, or Trific 60DF. A slightly higher rate and deeper incorporation may be specified for shattercane control.

Sonalan 3E (ethalfluralin) may be applied at 1.5 to 3 pints per acre within 3 weeks before planting and should be incorporated within 2 days after application. There is a greater risk of soybean injury from Sonalan than from trifluralin, so incorporation must be uniform. Sonalan is less likely than trifluralin to carry over and injure corn the following year.

Prowl 3.3E (pendimethalin) may be applied at 1.8 to 4.8 pints per acre up to 60 days (less for some tank-mixes) before planting soybeans. Preplant treatments should be incorporated within 7 days unless adequate rainfall occurs to incorporate the herbicide. *South of Interstate 80,* Prowl may be applied preemergence up to 2 days after planting.

Command 4E (clomazone) is used at 1.5 to 2 pints per acre to control annual grasses, velvetleaf, and several other broadleaf weeds. Use the higher rate if Command is applied more than 30 days prior to planting. Command is also used at lower rates in some tank-mixes for velvetleaf control. Command can be used preplant prior to *drilled no-till soybeans* if the drill is equipped with fluted or wavy coulters and spring tines or harrow to enhance incorporation. Plant at 6 miles per hour or more for adequate incorporation. Planting can be delayed 8 hours if the soil is dry, but plant immediately if the soil is moist. **Commence 5.25L** is a premix of Command and Treflan used at 1.75 to 2.67 pints per acre.

Incorporate Command or Commence immediately if the soil is moist or within 8 hours after application if the soil is dry. *You must minimize drift (spray or vapor) to sensitive plants.* Do not apply within 100 feet of trees, ornamentals, vegetables, alfalfa, or small grains or within 1,000 feet of subdivisions or towns, nurseries, greenhouses, and commercial fruit or vegetable (except sweet corn) production areas.

Minimum recropping intervals are 9 months for field corn or sorghum and 12 months for wheat. See Table 2 or the label for more information. Carryover injury will appear as whitened or bleached plants after emergence. Corn has usually outgrown modest injury with little effect on yield. However, injury may be severe if application or incorporation is not uniform. Corn hybrids vary in tolerance to clomazone.

Dual (metolachlor) and Lasso or Micro Tech (alachlor) can be applied preplant or preemergence to control annual grasses and pigweed. Use the higher rates to improve black nightshade control and incorporate to improve yellow nutsedge control. They can be combined with other herbicides to improve broadleaf control. Dual can be applied up to 30 days prior to planting soybeans. The rate per acre is 1.5 to 3 pints of 8E or 6 to 12 pounds of 25G. Lasso or Micro Tech can be applied up to 30 days prior to planting soybeans. The rate per acre is 2 to 3 quarts of 4E or Micro Tech 4ME. Arena, Judge, Stall, Saddle, and Confidence are private brands of alachlor. Partner 65DF and Micro Tech are encapsulated formulations of alachlor. *Products containing alachlor are restricted-use pesticides.*

Freedom is a premix of alachlor (Lasso) and trifluralin (Treflan) which can be applied up to 14 days prior to planting soybeans. It controls the same weeds as Lasso but requires incorporation within 24 hours because of the trifluralin. Freedom 3E rate is 2.75 to 5.5 quarts per acre. *Freedom is a restricted-use pesticide.*

Soil-Applied "Broadleaf" Herbicides (Soybeans)

Canopy, Command, Lexone, Lorox, Lorox Plus, Preview, Pursuit, Scepter, and Sencor are soil-applied herbicides used for broadleaf weed control in soybeans (see Table 12 for weeds controlled). Lorox is not to be incorporated and Command should be incorporated (Command is discussed in the "grass" herbicide section). The others can be used preplant-incorporated or preemergence after planting soybeans.

Timely rainfall or incorporation is needed for uniform herbicide placement in the soil. Incorporation may improve control of deep-germinating (large-seeded) weeds, especially when soil moisture is limited. Accurate and uniform application and incorporation are essential to minimize potential soybean injury. Except for Command, these herbicides are photosynthetic inhibitors (PSI), meristematic inhibitors (MSI), or premixes of MSI (chlorimuron) and PSI (metribuzin or linuron).

Photosynthetic Inhibitors

Metribuzin (Sencor or Lexone) and linuron (Lorox or Linex) are photosynthetic inhibitors (PSI). Preview, Salute, and Canopy are premixes that contain metribuzin, whereas Lorox Plus is a premix that contains linuron. These PSI herbicides can cause soybean injury from foliar or soil uptake, *so do not apply them after soybeans emerge.*

PSI herbicide injury symptoms are yellowing (chlorosis) and dying of lower soybean leaves, usually appearing about the first trifoliate stage. Atrazine and simazine carryover can intensify these symptoms. Soybeans usually recover from moderate PSI injury that occurs early. Metribuzin injury may be greater on soils with pH over 7.0. Soybean varieties differ in their sensitivity to metribuzin.

Sencor or Lexone (metribuzin) may be applied anytime within 14 days before planting soybeans. The Sencor or Lexone rate per acre used in tank-mixes is 1/2 to 1 pint of 4L or 1/3 to 2/3 pound of 75DF. Accurately adjust the rates according to soil texture and organic matter content. *Do not apply to sandy soil that is low in organic matter. Do not use on soils with pH greater than 7.5.* Reduced rates minimize soybean injury but lessen weed control. Split preplant and preemergence applications allow higher rates to improve weed control. Sencor or Lexone can control several annual broadleaves and can be tank-mixed with many herbicides to broaden the spectrum of control (see Table 10).

Turbo 8E, a premix of metribuzin (Sencor) plus metolachlor (Dual), can be applied preplant-incorporated or preemergence. The rate per acre is 1.5 to 3.5 pints.

Salute 4E, a premix of metribuzin (Sencor) plus trifluralin (Treflan), is applied preplant at 1.5 to 3 pints per acre and must be incorporated within 24 hours.

Preview 75DF and Canopy 75DF are premixes of metribuzin (Lexone) and chlorimuron (Classic), whereas **Lorox Plus 60DF** is a premix of linuron (Lorox, see next entry) and chlorimuron (Classic). These premixes may be applied preemergence or preplant-incorporated. They control cocklebur, velvetleaf, and wild sunflower better than metribuzin or linuron alone (see Table 12). Combinations with the grass herbicides can improve grass control (see Tables 10 and 11).

Broadcast rates per acre are 6 to 10 ounces of Preview 75DF, 4 to 7 ounces of Canopy 75DF, and 12 to 18 ounces of Lorox Plus 60DF. *Do not apply Preview, Canopy, or Lorox Plus to soils with pH greater than 6.8.* High soil pH may occur in localized areas in a field. Correct rate selection for the soil plus uniform, accurate application and incorporation are essential to minimize soybean injury and potential follow-crop injury. See PSI injury symptoms (above) and MSI injury symptoms (below).

Minimum recropping intervals for Preview, Canopy, and Lorox Plus are 4 months for wheat and 10 months for field corn. If Classic, Pursuit, or Scepter is applied the same year as Preview, Canopy, or Lorox Plus, the risk of carryover can increase, so labels should be checked carefully for rotational guidelines.

Lorox or Linex (linuron) is used after planting soybeans and before the crop emerges. Linuron is best suited to the silt loam soils of southern Illinois that contain 1 to 3 percent organic matter where the rate per acre is 1 to 1-2/3 pounds of 50DF or 1 to 1-2/3 pints of 4L per acre. *Do not apply to very sandy soils or soils containing less than 0.5 percent organic matter.*

Command (clomazone) is often used as a broadleaf herbicide in tank mixes, but it also controls annual grasses. Command is a pigment inhibitor and not a true photosynthesis inhibitor. See discussion under soil-applied "grass" herbicides.

Meristematic Inhibitors

Imazethapyr (Pursuit), imazaquin (Scepter), and chlorimuron (in Canopy, Preview, and Lorox Plus; see above) are meristematic inhibitors (MSI). See Table 12 for weeds controlled. *MSI herbicide injury symptoms* include temporary yellowing of upper leaves (golden tops) and shortened internodes of soybeans. Although plants may be stunted, yield is generally not affected. These MSI herbicides may carry over and injure certain sensitive follow crops. Symptoms on corn or grain sorghum are stunted growth, inhibited roots, and interveinal chlorosis or purpling of leaves. Symptoms on small grains are stunted top growth and excess tillering.

Pursuit 2E (imazethapyr) is used at 4 fluid ounces per acre (1 gallon per 32 acres) to control broadleaf weeds (see Table 12). Velvetleaf and jimsonweed control are more consistent with incorporation. Grass control is improved by tank-mixing Pursuit with a grass herbicide (see Table 10). **Pursuit Plus and Passport** are both premixes of Pursuit and Prowl or trifluralin, respectively. Both are used at 2.5 pints per acre, which is equivalent to 0.25 pint of Pursuit plus 2.1 pints of Prowl 3.3L, or 1.5 pints of trifluralin, respectively.

Pursuit and Pursuit Plus can be applied up to 45 days prior to planting soybeans. If sufficient rain does not occur before planting, then incorporate mechanically. *South of Interstate 80,* Pursuit Plus can be surface-applied up to 2 days after soybean planting. Minimum recropping intervals for Pursuit, Pursuit Plus, and Passport are 4 months for wheat, 9.5 months for field corn, and *18 months for grain sorghum.* Pursuit has less potential than Scepter to injure corn the next season and provides better control of velvetleaf. Thus, Pursuit is more adapted than Scepter to most soils of central and northern Illinois.

Scepter (imazaquin) is used at 2/3 pint 1.5E or 2.8 ounces of 70DG per acre and, if incorporated, is applied within 45 days (less with many tank mixes) before planting. Surface applications may be made up to 30 days before planting, during planting, or after planting but before the crop emerges. Scepter controls many broadleaf weeds such as pigweed and cocklebur (see Table 12) with adequate soil moisture, but it is somewhat weak on velvetleaf. Incorporation can improve weed control under low-rainfall conditions, and may improve control of velvetleaf and giant ragweed. Grass control is improved by mixing with "grass" herbicides (see Table 10).

Squadron and Tri-Scept are premixes of imazaquin (Scepter) plus pendimethalin (Prowl) or trifluralin, respectively. The rate per acre is 3 pints of Squadron or 2.33 pints of Tri-Scept, which is the equivalent of 2/3 pint of Scepter plus 1.5 pints of Prowl or trifluralin per acre. Incorporate Squadron within 7 days unless sufficient rain occurs. Tri-Scept must be incorporated within 24 hours.

A line across Peoria, extending west along Illinois Route 116 and east along U.S. Route 24, delineates Scepter, Squadron, or Tri-Scept rotational crop restrictions in Illinois (see Table 2). Region 3 is north of the line; Region 2 is south of the line.

There have been significant problems with carryover of Scepter and related premixes and tank mixes in Illinois. Soil and climatic conditions plus lack of uniformity in application and incorporation are associated with the carryover problem.

The potential for carryover is greater on soils with high organic matter and low pH. *Research and field results indicate that in Illinois, Scepter, Squadron, and Tri-Scept are best adapted to the soils and weeds south of Interstate 70.* Reduced rates, which can reduce potential carryover, are allowed for postemergence use of Scepter and in tank mixes with several other products. Imidazolinone-tolerant or -resistant hybrids can be used to minimize carryover problems.

Postemergence Herbicides (Soybeans)

Postemergence (foliar) herbicides are more effective when used in a planned program so that application is timely and not just an emergency or rescue treatment. Foliar treatments allow the user to identify the problem weed species and choose the most effective herbicide. Climatic conditions greatly affect foliar herbicides as penetration and action are usually greater with warm temperatures and high relative humidity. Rainfall soon after application can cause poor weed control. Weeds growing under droughty conditions are more difficult to control.

Rates and timing for foliar treatments are based on weed size. Early application when weeds are young and tender may allow the use of lower herbicide rates. Treatment of oversized weeds may only suppress growth temporarily, and regrowth may occur. A cultivation 7 to 14 days after application but before regrowth can often improve weed control. However, cultivation during or within 7 days of a foliar application may cause erratic weed control.

Crop-oil concentrates (COC) or nonionic surfactants (NIS) are usually added to the spray mix to improve postemergence herbicide effectiveness. A COC can be either petroleum oil (POC) or vegetable oil (VOC) based. VOC is sometimes methylated to form esters while NIS sometimes has fatty acids added to improve penetration. Dash is a special surfactant primarily for use with Poast. Fertilizer adjuvants such as 28-0-0 (UAN) or 10-34-0 may be specified on the label to increase control of certain weed species, such as velvetleaf. *Do not use brass or aluminum nozzles with fertilizer adjuvants. All fertilizer adjuvants should be rinsed from the tank before final cleanup with chlorine bleach.*

Postemergence herbicides for soybeans are either contact or translocated in action. Contact herbicides affect only the leaf tissue covered by the spray, so thorough spray coverage is critical. Contact herbicides should be applied to small weeds. Injury symptoms are usually noticeable within a day. Translocated herbicides do not require complete spray coverage as they move to the growing points (meristems) after foliar penetration. Their action is slow and symptoms may not appear for a week.

Contact Herbicides for Postemergence Control of Broadleaf Weeds (Soybeans)

Basagran, Blazer, Reflex, Cobra, Galaxy, and Storm are contact broadleaf herbicides. See Table 13 for weeds controlled. Table 14 gives herbicide rate by weed height or stage of growth. Spray volumes for ground application are 20 to 30 gallons per acre, and spray pressure should be 40 to 60 psi. Hollow cone or flat-fan nozzles provide much better coverage than flood nozzles.

Low temperatures and humidity will reduce contact activity. Soybean leaves may show contact burn under conditions of high temperature and humidity. This leaf burn is intensified by crop-oil concentrate or Dash. Soybeans usually recover within 2 to 3 weeks after application. A rain-free period of several hours is required for effective control with most contact herbicides.

Smaller weeds that are actively growing may allow the use of reduced herbicide rates. Most contact herbicides have little soil residual activity, so do not apply too early. Apply 2 to 3 weeks after soybean emergence or when soybeans are in the one- to two-trifoliate stage. Larger weeds not only require increased rates, but the weeds may recover and regrow. Contact herbicides should not be applied after soybeans begin to bloom. Preharvest intervals are generally 50 to 90 days.

Basagran (bentazon) is used at 1 to 2 pints per acre. See Table 14 for specifics on weed sizes and rates. Most weeds should be small (1 to 3 inches) and actively growing. Velvetleaf control is improved if 28-0-0 (UAN) is added to the spray mixture. Crop-oil concentrate is preferred if the major weed species are common ragweed or lambsquarters. Split applications can improve control of lambsquarters, giant ragweed, wild sunflower, and yellow nutsedge. Adding 2,4-DB can improve annual morningglory control. Do not spray if rain is expected soon after application.

Blazer (acifluorfen) is used at 0.5 to 1.5 pints per acre when broadleaf weeds are 2 to 4 inches tall and actively growing. Split applications are allowed 15 days apart, but do not apply more than 2 pints per acre per season. See the label for specifics on adjuvants, and see Table 14 for rates and weed sizes. Velvetleaf control is improved with the use of fertilizer adjuvants or the addition of Basagran. Adding 2,4-DB can improve cocklebur and morningglory control. Blazer may cause soybean leaf burn. However, the crop usually recovers within 2 to 3 weeks. Do not spray if rain is expected within 4 to 6 hours.

Basagran plus Blazer improves control of pigweed and morningglory over Basagran alone. **Storm 4S and Galaxy 3.67S** are premixes of Basagran and Blazer. Storm at 1.5 pints per acre is equivalent to 1 pint of Basagran plus 1 pint of Blazer. Galaxy at 2 pints per acre is equivalent to 1.5 pints of Basagran plus 0.67 pint of Blazer. See the labels for adjuvant specifics.

Cobra 2E (lactofen) is applied at 12.5 fluid ounces per acre with crop-oil concentrate (COC) at 0.5 to 1 pint per acre. One gallon per acre of 28-0-0 (UAN) may be substituted for COC under favorable growing conditions. Reduced rates are used in some combination. See Table 14 for weed size. Cobra usually causes soybean leaf burn, but soybeans usually recover within 2 to 3 weeks. Apply Cobra only once during the season and no later than 90 days before harvest. Do not apply if rain is expected within 30 minutes.

Reflex 2LC (fomesafen) is used at 0.75 to 1 pint per acre north of Interstate 70 and at 1.25 pints south of Interstate 70. **Tornado 1.75E,** a premix of fomesafen and fluazifop-P, is used at 1 quart per acre (equivalent to 1 pint of Reflex and 1.5 pints of Fusilade) to control broadleaf and grass weeds. Add crop-oil concentrate or nonionic surfactant with Reflex or Tornado.

Reflex or Tornado should be applied before soybeans bloom. Do not spray if rain is expected within 4 hours of application. Be sure applications are accurate and even as there is a potential for carryover with fomesafen. Do not apply Reflex or Tornado to any field more than once every 2 years. Recrop intervals are 4 months for small grains, 10 months for corn, and 18 months for other crops.

Translocated Herbicides for Postemergence Control of Broadleaf Weeds (Soybeans)

Classic, Pinnacle, Pursuit, and Scepter are translocated herbicides that primarily control broadleaf weeds in soybeans. See Table 13 for weeds controlled. Table

15 gives herbicide rate by weed height or stage of growth. All four have the same mode of action and some soil residual activity. Weeds should be actively growing (not moisture- or temperature-stressed). Do not make applications when weeds are in the cotyledon (very early seedling) stage. Annual weeds are best controlled when less than 3 to 5 inches tall (within 2 to 4 weeks after soybean emergence). A 1-hour rain-free period after application is usually adequate for these herbicides.

These herbicides inhibit growth of new meristems, so symptoms of weed injury may not be exhibited for 3 to 7 days. Injury symptoms are yellowing of leaves followed by death of the growing point. Death of leaf tissue in susceptible weeds is usually observed in 7 to 21 days. Less susceptible plants may be suppressed, remaining green or yellow but stunted for 2 to 3 weeks.

Soybeans may show temporary leaf yellowing (golden tops), growth retardation (stunting), or both, especially if the soybeans are under stress. Under favorable conditions, affected soybeans may recover with only a slight reduction in height and no loss of yield.

Total spray coverage is not critical for translocated herbicides. A minimum spray volume of 10 gallons per acre may be used for ground application using flat-fan nozzles at 20 to 40 psi or hollow cone nozzles at 40 to 60 psi. Nonionic surfactant (NIS) is usually specified at 1 to 2 pints per 100 gallons of spray. Crop-oil concentrate (COC) may improve weed control but may increase crop injury. Fertilizer additives (28-0-0 or 10-34-0) improve control of some weeds and are specified for velvetleaf control on the Classic, Pinnacle, and Pursuit labels. *Tank-mixing these herbicides with postemergence herbicides for grass may reduce grass control, so sequential applications are often specified* (Table 16).

Classic 25DF (chlorimuron) is used at 0.5 to 0.75 ounce per acre plus 1 quart of surfactant or 1 gallon of crop-oil concentrate per 100 gallons. Fertilizer adjuvants improve velvetleaf control. Pigweed control varies with rate and species. Check the label or Table 15 for weed sizes and rates. Split applications can improve control of burcucumber, giant ragweed, and annual morningglory. Do not apply Classic within 60 days of harvest. Recrop intervals are 3 months for small grains and 9 months for field corn, sorghum, alfalfa, or clover. If Classic is applied after Preview, Canopy, Lorox Plus, Pursuit, or Scepter, check the label for recrop intervals as carryover injury to corn can occur, especially if soil pH is above 6.8. Corn will appear stunted with interveinal chlorosis or purpling of leaves and inhibition of roots.

Pinnacle 25DF (thifensulfuron) is used at 0.25 ounce per acre to control lambsquarters, pigweed, smartweed, and velvetleaf. See Table 15 for weed sizes. The addition of 1 gallon of UAN (28-0-0) per acre improves velvetleaf control. Tank-mixing with 0.25 ounce of Classic 25DF per acre with Pinnacle can improve control of cocklebur, jimsonweed, and wild sunflower. Add nonionic surfactant at 1 to 2 pints per 100 gallons. *Do not use crop-oil concentrate unless conditions are droughty.* Pinnacle has less persistence than Classic. Any crop may be planted 45 days after application of Pinnacle alone. For the Classic plus Pinnacle tank mix, the Classic recropping intervals apply.

Pursuit 2E (imazethapyr) is used at 0.25 pint per acre plus surfactant at 1 quart per 100 gallons of spray. Add 1 quart per acre of 28-0-0 or 10-34-0. (See Table 15 for weed sizes.) Lambsquarters, common ragweed, and annual morningglory control may be poor. It can also provide control of foxtails and shattercane but not volunteer corn. Do not apply Pursuit within 85 days of soybean harvest. Recropping intervals are 4 months after application for wheat, 9.5 months for field corn, and 18 months for other field crops *including grain sorghum.* See Table 2. Do not apply products containing chlorimuron or imazaquin the same year as Pursuit because such combinations increase the potential for injury to subsequent crops.

Scepter (imazaquin) can be used postemergence to control pigweed, cocklebur, wild sunflower, and volunteer corn in soybeans. The low rate is 1/3 pint of 1.5E or 1.4 ounces of 70DG. A higher rate is labeled, but rotational guidelines change. Scepter is better on cocklebur and volunteer corn, but Pursuit is better on velvetleaf and shattercane. Use a nonionic surfactant at 1 quart per 100 gallons. Do not tank-mix Scepter with postemergence herbicides for grass control. Do not apply Scepter within 90 days of soybean harvest. Follow rotational guidelines on the Scepter label or see Table 2. Also see the recrop discussion on Scepter in the section on "Soil-Applied 'Broadleaf' Herbicides (Soybeans)."

Scepter O.T. is a premix combination with 0.5 pound a.i. of imazaquin and 2 pounds a.i. acifluorfen per gallon to broaden the spectrum of control to include annual morningglories, copperleaf, and smartweed. Rate is 1 pint per acre with addition of 1 quart nonionic surfactant per 100 gallons. The addition of 1 to 2 fluid ounces of 2,4-DB added to Scepter O.T. may further improve control of annual morningglories.

Translocated Herbicides for Control of Grass Weeds

Poast Plus, Assure II, Fusilade, Option II, Fusion, and Select can control many annual and perennial grasses in soybeans (see Table 11). Table 17 gives herbicide rate by size of grass weed. Pursuit also has some postemergence grass control. Grasses should be actively growing (not stressed or injured) and not tillering or forming seedheads. Cultivation within 5 to 7 days before or after application may decrease grass control. Addition of crop-oil concentrate is usually specified, especially if the weeds are somewhat droughty or label limitations on weed size are approached.

Rates vary by weed size and species, so consult the label or Table 17 before applying. Rate reductions may be optional on small weeds or under ideal conditions, whereas rate increases may be needed for larger weeds. Control of johnsongrass and quackgrass often requires follow-up applications for control of regrowth. *Volunteer cereals* such as wheat and rye can be controlled by Assure II, Fusion, or Fusilade; Poast Plus or Select can provide good control if the plants have not tillered or overwintered.

Specified spray volume per acre is 10 to 20 gallons for ground application or 3 to 5 gallons for aerial application. A 1-hour rain-free period after application is needed. Avoid drift to sensitive crops such as corn, sorghum, or wheat. Apply before bloom stage of soybeans and at least 80 to 90 days before harvest.

These herbicides do not control broad-leaved weeds. Most labels allow tank-mixing with certain broadleaf herbicides, but limitations are made as to rate, timing, and spray coverage. *Check the label before applying grass and broadleaf herbicide tank mixes or sequences. Control of grass weeds may be reduced or increased rates may be specified.*

Poast Plus 1.0E (sethoxydim) is used at 1.5 pints per acre to control most annual grasses including foxtails, fall panicum, volunteer corn, or shattercane. See the label or Table 17 for weed sizes and special rates for smaller or larger weeds. Fertilizer adjuvants are specified for control of volunteer corn and shattercane. Always add 2 pints per acre of Dash or crop-oil concentrate. See the "Problem Perennial Weeds" section below for control of perennial grasses.

Assure II 0.88E (quizalofop) is used at 7 fluid ounces per acre to control foxtails and fall panicum. Use 5 fluid ounces per acre to control volunteer corn or shattercane. Add either 1 gallon of crop-oil concentrate or 1 quart of nonionic surfactant per 100 gallons of spray. Refer to the label or Table 17 for rates and weed sizes. See the "Problem Perennial Weeds" section for perennial grass control.

Fusilade 2000 1E (fluazifop-P) is applied at 0.75 pint per acre for volunteer corn, shattercane, or seedling johnsongrass. Refer to the label or Table 17 for weed sizes and rates. Add either 1 gallon of crop-oil concentrate or 1 quart of nonionic surfactant per 100 gallons of spray. See "Problem Perennial Weeds" for control of perennial grasses.

Fusion 2.66E (fluazifop + fenoxaprop) is a premix of Fusilade and Option to improve the annual grass control of Fusilade. The rate is 6 to 8 fluid ounces per acre when used alone or 8 to 10 fluid ounces when tank-mixed. Reduced rates are allowed on susceptible weeds when applied under optimum growing conditions. See Table 17 for maximum height limitations and rates. Always add crop-oil concentrate or nonionic surfactant with Fusion.

Option II 0.79E (fenoxaprop) is used at 0.4 to 0.8 pint per acre to control most annual grass weeds (see Table 17). Add crop-oil concentrate to control most grasses; do not use COC on rhizome johnsongrass. See Table 17 or 18 for control of perennial grasses.

Select 2E (clethodim) is used at 6 to 8 fluid ounces plus a quart of crop-oil concentrate per acre for control of annual grass weeds. Use the lower rate under minimum grass pressure and/or when grasses are less than maximum height. Table 17 lists rates and grass height limits. Rhizome johnsongrass and quackgrass will require higher rates and may require two applications (see "Problem Perennial Weeds" below).

Roundup (glyphosate) may be applied through wiper applicators to control volunteer corn, shattercane, and johnsongrass. Hemp dogbane and common milkweed may also be suppressed. Weeds should be at least 6 inches taller than the soybeans to avoid contact with the crop. Adjust the height of the applicator so that the wiper contact is at least 2 inches above the soybean plants. Mix 1 gallon of Roundup with 2 gallons of water for wiper applicators. Spot treatment can be made on a spray-to-wet basis using a 2 percent solution of Roundup in water. Motorized spot treatment may provide less complete spray coverage of weeds, so use a 5 percent solution of Roundup. Minimize spray contact with the soybeans.

Soybean Preharvest Treatments

Roundup can be applied *preharvest* in soybeans after soybean pods have set and lost all green color. Allow a minimum of 7 days between application and soybean harvest. By air, Roundup may be applied at a rate of 1 quart per acre. Ground application at a higher rate is also allowed but is usually only feasible for spot treatment. Do not graze or harvest treated crop for livestock feed within 25 days of the last preharvest application. Do not treat soybeans grown for seed beans as there may be a reduction in germination or vigor.

Gramoxone Extra (paraquat) may be used for drying weeds in soybeans just before harvest. For indeterminate varieties (most of the varieties planted in Illinois), apply when 65 percent of the seed pods have reached a mature brown color or when seed moisture is 30 percent or less. For determinate varieties, apply when at least half of the leaves have dropped and the rest of the leaves are turning yellow.

The rate is 12.8 ounces of Gramoxone Extra 2.5S. The total spray volume per acre is 2 to 5 gallons for aerial application and 20 to 40 gallons for ground application. Add 1 quart of nonionic surfactant per 100 gallons of spray. Do not pasture livestock within 15 days of treatment, and remove livestock from treated fields at least 30 days before slaughter. *Gramoxone Extra is a restricted-use pesticide.*

Problem Perennial Weeds

Perennial weeds are increasing in Illinois because of reduced tillage, less crop rotation, and reduced competition from annual weeds.

Perennial weeds are often found in dense localized infestations or lightly scattered in fields. Even small populations can cause reductions in crop yield, grain quality, and harvesting efficiency and can become serious infestations if left untreated.

Control of most perennials is often difficult due to the fact that perennials reproduce both by vegetative propagation and by seed. Light tillage, such as the use of a chisel plow or field cultivator, may drag root sections about the field where new shoots emerge and the problem spreads. If tillage is to be beneficial, root sections displaced by tillage must be exposed to the freeze-thaw cycle of winter weather or left on the soil surface to desiccate. Repeated mowings, where possible, or row cultivation can deplete food reserves these plants store in the roots.

Effective control of perennial weeds will often rely on a combination of mechanical control methods and the use of translocated (systemic) herbicides. Tillage and herbicide applications used together will weaken the vegetative regeneration of plant parts and suppress seedling development. Since no program is completely effective, elimination of perennial weeds from a single location may take several years. When using systemic herbicides, control of perennials is often more effective when low-dosage, multiple treatments are applied. This results in better movement of the herbicide into the roots and a more complete kill of perennial plant parts. Contact herbicides may suppress certain perennials but will not be effective in preventing regrowth from plant roots.

Table 18 lists common herbicides that are recommended for control or suppression of many perennial weeds. Although not indicated in this table, it should be emphasized that isolation of an infested area is often necessary to effectively treat perennial weeds. This can be done by rotating the affected field to small grains or forage legumes, government set-aside, or to a crop for which herbicides or mechanical controls can be used.

With many perennial weed infestations, if the affected area is small enough or if plants are lightly scattered through a field, spot treatment with a 2 percent solution of Roundup (3 ounces in 1 gallon) in a hand-held sprayer is highly effective. Although Roundup is nonselective and must be kept from contacting desirable vegetation, it can be applied to perennial weeds almost any time they are actively growing and have sufficient foliage to absorb and translocate the herbicide.

Roundup can also be used in wiper applicators and applied to weeds exceeding crop height by at least 6 inches. For wiper applicators, dilute 1 gallon of Roundup in 2 gallons of water. Do not till for 5 days before or after applying Roundup.

Table 18 includes recommendations for control of the most common perennial weeds in Illinois. Observe all precautions (listed on the herbicide labels) regarding drift and crop injury when applying these herbicides.

Contributions of other weed scientists and staff of the University of Illinois and at other institutions as well as the input of industry weed scientists is gratefully acknowledged.

Table 1. Herbicide and Herbicide Premix Names and Restrictions

Trade name	Common (generic) name(s)	RUP[a]	GWA[b]	Signal word[c]
AAtrex, atrazine	Atrazine	Yes	Yes	Caution
Accent	Nicosulfuron	—	—	Caution
Assure II	Quizalofop	—	—	Caution
Banvel	Dicamba	—	—	Warning
Basagran	Bentazon	—	—	Caution
Beacon	Primisulfuron	—	—	Caution
Bicep	Metolachlor + atrazine	Yes	Yes	Caution
Bladex	Cyanazine	Yes	Yes	Warning
Blazer	Acifluorfen	—	—	Danger
Bronco	Alachlor + glyphosate	Yes	Yes	Danger
Buctril	Bromoxynil	—	—	Warning
Buctril + Atrazine	Bromoxynil + atrazine	Yes	Yes	Caution
Bullet	Alachlor + atrazine	Yes	Yes	Caution
Butyrac 200	2,4-DB	—	—	Danger
Canopy	Metribuzin + chlorimuron	—	Yes	Caution
Classic	Chlorimuron	—	—	Caution
Cobra	Lactofen	—	—	Danger
Command	Clomazone	—	—	Warning
Commence	Clomazone + trifluralin	—	—	Warning
Cycle	Metolachlor + cyanazine	Yes	Yes	Caution
Dual	Metolachlor	—	Yes	Caution
Eradicane	EPTC + safener	—	—	Caution
Extrazine II	Cyanazine + atrazine	Yes	Yes	Warning
Freedom	Alachlor + trifluralin	Yes	Yes	Warning
Fusilade 2000	Fluazifop	—	—	Caution
Fusion	Fluazifop + fenoxaprop	—	—	Caution
Galaxy	Bentazon + acifluorfen	—	—	Danger
Gramoxone Extra	Paraquat	Yes	—	Danger-Poison
Laddok	Bentazon + atrazine	Yes	Yes	Danger
Lariat	Alachlor + atrazine	Yes	Yes	Warning
Lasso EC	Alachlor	Yes	Yes	Danger
Lexone	Metribuzin	—	Yes	Caution
Lorox	Linuron	—	—	Caution
Lorox Plus	Linuron + chlorimuron	—	—	Warning
Marksman	Dicamba + atrazine	Yes	Yes	Caution
Many trade names	2,4-D dimethylamine	—	—	Danger
Many trade names	2,4-D ester	—	—	Caution
Micro Tech	Alachlor	Yes	Yes	Caution
Option II	Fenoxaprop	Yes	—	Danger
Passport	Trifluralin + imazethapyr	—	—	Danger
Pinnacle	Thifensulfuron	—	—	Caution
Poast Plus	Sethoxydim	—	—	Caution
Preview	Metribuzin + chlorimuron	—	Yes	Caution
Princep, Simazine	Simazine	—	Yes	Caution
Prowl	Pendimethalin	—	—	Warning
Pursuit	Imazethapyr	—	—	Caution
Pursuit Plus	Pendimethalin + imazethapyr	—	—	Caution
Ramrod/atrazine	Propachlor + atrazine	Yes	Yes	Warning
Reflex	Fomesafen	—	—	Warning
Roundup	Glyphosate	—	—	Warning
Salute	Metribuzin + trifluralin	—	Yes	Caution
Scepter	Imazaquin	—	—	Caution
Select	Clethodim	—	—	Warning
Sencor	Metribuzin	—	Yes	Caution
Sonalan	Ethalfluralin	—	—	Warning
Squadron	Imazaquin + pendimethalin	—	—	Danger
Stinger	Clopyralid	—	Yes	Caution
Storm	Bentazon + acifluorfen	—	—	Danger
Sutan+	Butylate + safener	—	—	Caution
Sutazine	Butylate + atrazine	Yes	Yes	Danger
Tornado	Fluazifop + fomesafen	—	—	Warning
Treflan,Tri-4, Trific, Trilin	Trifluralin	—	—	Warning
Tri-Scept	Imazaquin + trifluralin	—	—	Danger
Turbo	Metribuzin + metolachlor	—	Yes	Caution

[a] RUP = Restricted-use pesticide to be applied by licensed applicator.
[b] GWA = Groundwater advisory; special precautions in sandy soils.
[c] Signal word = Toxicity signal; indicates need for extra precautions. The signal words "Danger" and "Warning" often indicate pesticides that can irritate skin and eyes, necessitating protective clothing, gloves, and goggles or face shield.

Table 2. Herbicide Crop Rotation Restrictions — Months

Herbicide	pH	Corn	Milo	Wheat	Oats	Rye	Alfalfa	Clover	Soybeans
Accent	...	AT[a]	10[b]	4	8	4	10	10[b]	10
Assure	...	4	4	4	4	4	4	4	AT
Atrazine	<7.2	AT	AT	15	21	21	21	21	10[c]
Banvel[d]	...	AT	0.5	1	1	1	4	4	0.5
Beacon	...	0.5	8	3	8	3	8	18	8
Bicep	...	AT	AT*	15	15	15	18	18	10[c]
Buctril/atrazine	...	AT	AT	15	21	15	21	21	10[c]
Bullet	...	AT	AT*	15	21	15	21	21	10[c]
Canopy[e]	≤6.8	10	12	4	18[f]	18[f]	10	12	AT
Classic	<7.0	9	9[g]	3	3	3	9[g]	9[g]	AT
Command	...	9	9	12	16	16	16	16	AT
Commence	...	9	12	12	16	16	16	16	AT
Cycle	...	AT	AT*	4.5	4.5	4.5	4	9	9
Dual	...	AT	AT*	4.5	4.5	4.5	4	9	AT
Extrazine	...	AT	AT	15	15	15	18	18	10[c]
Fusion	...	2	2	2	2	2	2	2	AT
Laddok	...	AT	AT	9	9	9	18	18	10[c]
Lariat	...	AT	AT*	15	21	15	21	21	10[c]
Lexone	...	4	12	4	12	12	4	12	AT
Lorox Plus	≤6.8	10	10	4	4	4	10	12	AT
Marksman	...	AT	AT	10	10	10	18	18	10[c]
Passport	...	9.5	18	4	18	18	18	18	AT
Pinnacle	...	1.5	1.5	1.5	1.5	1.5	1.5	1.5	AT
Preview	≤6.8	10	12	4	BA[f]	BA[f]	10	12	AT
Princep	...	AT	12	15	21	21	21	21	10[c]
Pursuit	...	9.5	18	4	18	4	18	18	AT
Pursuit Plus	...	9.5	18	4	18	18	18	18	AT
Reflex	...	10	18	4	4	4	18	18	AT
Salute	...	4	12	4	12	12	4	12	AT
Scepter — Region 3									
1/3 pt/A	...	11	11	4[i]	4	18	18	18	AT
2/3 pt/A	...	18	11	16	16	18	18	18	AT
Scepter[h]	...	11[i]	11	4[i]	11	18	18	18	AT
Sencor	...	4	12	4	12	12	4	12	AT
Squadron[h]	...	11[i]	11	4[i]	11	18	18	18	AT
Stinger	...	AT	AT	AT	AT	AT	12	18	12
Sutazine	...	AT	12	15	15	15	18	18	10[c]
Tri-Scept[h]	...	11[i]	11	4[i]	11	18	18	18	AT
Turbo	...	8	12	4.5	12	12	12	12	AT

The following have no labeled rotational restrictions: Basagran, Bladex, Blazer, Bronco, Butyrac 200, Cobra, Eradicane, 2,4-D, Galaxy, Gramoxone Extra, Lasso, Poast Plus, Roundup, Sonalan, Storm, Sutan, and Treflan except for Eradicane, 2,4-D, and Sutan + that have replanting limits for soybeans.
* Seed protectant is needed.
[a] AT = anytime (no restrictions).
[b] 18 months if pH >6.5.
[c] If applied before June 10.
[d] From the between-cropping label.
[e] Reduced rate label for Midwest states.
[f] BA = bioassay after 10 months.
[g] 15 months if pH >7.
[h] Region 2 on Scepter label (approximately southern two-thirds of Illinois).
[i] 15-inch annual rainfall restriction or use imidazolinone-resistant or tolerant corn hybrids.

Table 3. No-Till Herbicides and Their Knockdown Control of Weeds

Herbicide	DBM	FPN	RYE	MST	PLC	MTD	LQR	CRW	SWD	HVC	ALF
Roundup	9	9	9	9	8	10	9	9	7	6	6
Gramoxone	7	7	8	7	6	10	8	8	7	7	3
2,4-D ester	0	0	0	8	9	10	9	10	7	10	8
Banvel	0	0	0	9	9	7	10	10	9	10	9
Atrazine	7	5	7	8	9	10	10	9	10	7	4
Bladex	7	8	5	9	9	10	9	10	9	8	4
Extrazine	7	7	6	9	9	10	9	10	9	8	4
Canopy	6	3	3	9	9	10	9	9	9	5	4
Pursuit	6	7	5	6	6	10	6	7	9	2	0

DBM = downy brome, FPN = fall panicum, RYE = rye or wheat, MTL = marestail*, PLC = prickly lettuce, MST = mustards, LQR = lambsquarters, CRW = common ragweed, SWD = smartweed, HVC = hairy vetch, ALF = alfalfa sod.

Rating Scale:
10 = 95 to 100 percent, 9 = 85 to 95 percent, 8 = 75 to 85 percent, 7 = 65 to 75 percent, and 6 = 55 to 65 percent. Weed control of 5 or less is rarely significant.

Table 4. Registered Herbicide Combinations for Preplant Incorporated, Preemergence, or Early Postemergence Application in Corn

	Atrazine	Bladex or Extrazine II	Banvel or Marksman	Pursuit[a]
Used alone	1,2,3	1,2,3	2,3	1,2,3
Eradicane	1	1	—	1
Sutan +	1	1	—	1
Dual	1,2,3	1,2	2,3	1,2,3
Micro Tech	1,2,3	1,2	2,3	1,2,3
Prowl	2,3	2[b],3[b]	2,3	2,3

1 = Preplant incorporated; 2 = Preemergence; 3 = Early postemergence; — = Not registered.
[a] Use Pursuit only with tolerant or resistant corn hybrids.
[b] Bladex, not Extrazine.

Table 5. Corn Herbicides: Preplant or Preemergence Rates per Acre

Herbicide	Unit	Organic matter:[a] Soil texture:[b]	1% sal	1-2% sil	3-4% sicl	5-6% sic
Atrazine 4L	pt		4.0	4.0	4.0	4.0
Atrazine 90DF	lb		2.2	2.2	2.2	2.2
Bicep 6L	pt		3.0	3.6	4.8	6.0
Bladex 4L	pt		2.5[c]	4-5	7-8	9.5
Bladex 90DF	lb		1.3[c]	2-3	4.4	5.3
Bronco 4L	pt		6.0	8.0	8-10	10.0
Bullet 4L	pt		5.0	6.0	8.0	9.0
Cycle 4L	pt		5.0[c]	6-7	8-9	9-10
Dual 8E	pt		1.5	2.0	2.5	2.5
Dual 25G	lb		6-8	8-10	10.0	12.0
Eradicane 6.7E	pt		4.75	4.75	5.3	5.3
Eradicane Extra 6E	pt		4.0	4.0	5.3	5.3
Extrazine 4L	pt		2.5[c]	4-5	6-7	8-9
Extrazine 90DF	lb		1.5[c]	2-3	4-5	5-5.5
Lariat 4L	pt		5.0	6.0	8.0	9.0
Lasso 4E	pt		3-4	3-4	4-5	5-6
Lasso II 15G	lb		16.0	20.0	22.0	26.0
Marksman 3.3L	pt		—[d]	—[d]	3.5	3.5
Micro Tech 4ME	pt		3-4	3-4	4-5	5-6
Partner 65DF	lb		3-4	4.5	4.5	5.5
Princep 4L	pt		4.0	4.8	6.0	8.0
Princep 90DF	lb		2.2	2.6	3.3	4.4
Prowl 3.3E	pt		2.0	2.4	3.6	4.0
Sutan+ 6.7E	pt		4.75	4.75	4.75	4.75
Sutazine 6L	pt		5.25	5.25	7.0	7.0

[a] Percent organic matter in the soil.
[b] sal = sandy loam, sil = silt loam, sicl = silty clay loam, sic = silty clay.
[c] Questionable due to crop injury or short persistence.
[d] Not recommended on this soil.

Table 6. Corn Herbicides: Grass and Nutsedge Control

Herbicide	BYG	CBG	FLP	GFT	YFT	WCG	SBR	SHC	WPM	JHG	QKG	WSM	YNS	CRN
Soil-applied														
Atrazine	8	5	3	7	7	4	7	2	3	0	8	3	6	0
Bladex	7	7	8	8+	8	6	7	2	7	0	3	0	5	2
Dual	8+	9	8+	9	9	7	7	5	7	0	0	0	7+	1+
Eradicane	9	9	9	9	9	8	8	7	7	6	5	2	8	1+
Extrazine	8	7	7	8	8	6	7	2	5	0	4	2	4	2
Micro Tech	8+	9	8	9	9	7	7	5	7	0	0	0	7	1
Princep	8	8	7	7	7	4	5	4	4	0	4	2	2	0
Prowl	8	9	8+	8+	8+	8	7	7	7	2	0	0	0	2
Pursuit[a]	6	7	7	7	6	6	5	7	4	4	2	0	4	1
Sutan+	9	9	9	9	9	8	9	7	7	6	6	5	7	1
Foliar-applied (*postemergence*)														
Accent	8	5	8	9	8	8	8	9+	8	9	8+	6	6	1
Atrazine/oil	8	5	5	7	7	6	7	2	4	0	7	6	6	1+
Beacon	4	5	7	6	5	2	6	9+	2	8	7	4	6	1+
Bladex	8	7	7	8	8	6	7	2	6	0	3	2	5	2
Pursuit[a]	8	7	7	8	7	5	4	9	3	6	0	2	6	1

BYG = barnyardgrass, CBG = crabgrass, FLP = fall panicum, GFT = giant foxtail, YFT = yellow foxtail, WCG = woolly cupgrass, SBR = sandbur, SHC = shattercane, WPM = wild proso millet, JHG = johnsongrass, QKG = quackgrass, WSM = wirestem muhly, YNS = yellow nutsedge, and CRN = corn response.
[a] Use only on Pursuit-resistant or -tolerant field corn hybrids.

Rating Scale:
10 = 95 to 100 percent, 9 = 85 to 95 percent, 8 = 75 to 85 percent, 7 = 65 to 75 percent, 6 = 55 to 65 percent, and 5 = 45 to 55 percent. Weed control of 5 or less is rarely significant. Corn injury of 1 or less is rarely significant.

Table 7. Corn Herbicides: Broadleaf Weed Control

Herbicide	AMG	BCC	CCB	JMW	LBQ	BNS	PGW	CRW	GRW	SMW	SFR	PSI	VLV	CRN
Soil-applied														
Atrazine	9	7	9	10	9	9	9	9	8	9	8	9	8	0
Bladex	8	4	8	8	9	8	6	9	7	9	7	8	7	2
Dual	0	0	0	4	6	7+	8	5	2	4	0	0	0	1+
Eradicane	3	0	2	2	7	4	7	5	3	4	0	0	5	1+
Extrazine	9	7	9	9	9	9	9	9	8	9	8	7	8	2
Marksman	8	6	8	8	8	8	9	9	8	9	8	7	7+	2
Micro Tech	0	0	0	5	7	7+	9	5	2	5	0	0	0	1
Princep	9	6	9	9	9	9	9	9	7	9	8	9	8	0
Prowl	0	0	0	2	8	0	9	2	0	4	0	0	6	2
Pursuit[a]	6	7	7	7	8	8	9	7	6	9	8	7	8	1
Sutan+	3	0	2	2	5	2	7	4	3	3	0	0	4	1
Foliar-applied (*postemergence*)														
Accent	7	8	4	8	5	0	8+	3	3	8	5	2	6	1
Atrazine/oil	9	8	9	9	9	9	10	9	8	10	9	9	9	1+
Banvel	9	7	9	9	9	8	9	9	9	10	8	7	7	1+
Beacon	5	8	8	8	6	7	8	9	9	8	8	8	7	1+
Bladex	7	5	8	8	9	9	6	9	7	9	7	6	7	2
Buctril	8	8	9	9	9	9	7+	9	7	8+	9	5	8	2
Buctril/atrazine	**9**	**9**	**9**	**10**	**10**	**10**	**10**	**9**	**9**	**10**	**10**	**9**	**9**	**2**
2,4-D	9	3	9	7	9	7	9	9	9	6	8	8	8	2+
Laddok	8	7	9	10	9	9	9	9	9	10	10	8	9	1
Marksman	9	8	9	10	10	10	10	9	9	10	9	9	9	1+
Pursuit[a]	7	8	9	8+	6	9+	9	7	7	8	9	6	8+	1+
Stinger	3	6	9	8	3	7	3	9	9	7	8	3	3	1

AMG = annual morningglory, BCC = burcucumber, CCB = cocklebur, JMW = jimsonweed, LBQ = lambsquarters, BNS = black nightshade, PGW = pigweed, CRW = common ragweed, GRW = giant ragweed, SMW = smartweed, SFR = wild sunflower, PSI = prickly sida, VLV = velvetleaf, and CRN = corn.
[a] Use only on Pursuit-resistant or -tolerant field corn hybrids.

Rating Scale and Approximate Weed Control
10 = 95 to 100 percent, 9 = 85 to 95 percent, 8 = 75 to 85 percent, 7 = 65 to 75 percent, and 6 = 55 to 65 percent.
Weed control of 5 or less is rarely significant. Corn injury of 1 or less is rarely significant.
For ratings on herbicide combinations (tank-mix or premix), see the component parts.

Premix:	Grass	+	Broadleaf
Bicep:	Dual	+	atrazine
Bullet:	Micro Tech	+	atrazine
Cycle:	Dual	+	Bladex
Extrazine:	Bladex	+	atrazine
Lariat:	Lasso	+	atrazine
Sutazine:	Sutan+	+	atrazine

Premix	Broadleaf	+	Broadleaf
Buctril + Atrazine:	Buctril	+	atrazine
Laddok:	Basagran	+	atrazine
Marksman:	Banvel	+	atrazine

Table 8. Postemergence Herbicide Tank-Mixes for Corn

Herbicide	Buctril	Basagran	Laddok	Banvel	Marksman	2,4-D	Atrazine
Accent	X	–	–	X	X	–	X
Atrazine	X	X	–	X	X	–	–
Beacon	X	–	–	X	–	X	–
Bladex	–	–	X	X	X	–	X
Pursuit	X	–	–	–	–	–	X
2,4-D	X	–	X	X	–	–	–

X = registered; X? = check current label; – = not registered.

Table 9. Soybean Herbicides: Preplant or Preemergence Rates per Acre

Herbicide	Unit	Organic matter:[a] Soil texture:[b]	1% sal	1-2% sil	3-4% sicl	5-6% sic
Bronco 4L	pt		6.0	8.0	8-10	10.0
Canopy 75DF	oz		5.0	6.0	6-7	7.0
Command 4E	pt		1.0	1.5	2.0	2.0
Commence 5.5L	pt		1.75	2.25	2.5	2.7
Dual 8E	pt		1.5	2.0	2.5	2.5
Dual 15G	lb		6-8	8-10	10.0	12.0
Freedom 3E	pt		5.5	6-7	7-8	8.0
Lasso 4E	pt		3-4	3-4	4-5	5-6
Lasso II 15G	lb		16.0	20.0	22.0	26.0
Lexone 75DF	lb		0.33[c]	0.33	0.50	0.67
Lorox 50DF	lb		0.75[c]	1.3	2.0[c]	[d]
Lorox + 60DF	oz		12.0	14.0	16.0	[d]
Micro Tech 4En	pt		3-4	3-4	4-5	5-6
Partner 65DF	lb		3-4	4.5	4.5	5.5
Passport 2.8E	pt		2.5	2.5	2.5	2.5
Preview 75DF	oz		6.0[c]	7.0	8-9	10.0[c]
Prowl 3.3	pt		1.5	2.0	2.4	3.0
Pursuit 2S	pt		0.25	0.25	0.25	0.25
Pursuit+ 2.9S	pt		2.5	2.5	2.5	2.5
Salute 4L	pt		1.5[c]	2.25	2.5	3.0
Scepter 1.5S	pt		0.67	0.67	0.67	0.67
Sencor 4L	pt		0.5[c]	0.67	0.75	1.0
Sencor 75DF	lb		—[d]	0.67	0.75	0.75-1
Sonalan 3E	pt		1.5	2.0	2.5	3.0
Squadron 2.3L	pt		3.0	3.0	3.0[d]	3.0[d]
Treflan 4E	pt		1.0	1.5	2.0	2.0
Tri-Scept 3S	pt		2.3	2.3	2.3[d]	2.3[d]
Turbo 8E	pt		1.5[c]	2.0	2.5	3.0

[a] Percent organic matter in the soil.
[b] sal = sandy loam, sil = silt loam, sicl = silty clay loam, sic = silty clay.
[c] Questionable due to crop injury or short persistence.
[d] Not recommended on this soil.

Table 10. Herbicide Tank-Mixes for Preplant-Incorporated or Preemergence Use in Soybeans

Herbicide	Sencor or Lexone	Canopy or Preview	Scepter[a]	Pursuit	Command	Lorox or Linex	Lorox Plus
Preplant Incorporated							
Command	1	1	1	—	—	—	—
Commence	1	1	1	—	—	—	—
Freedom	1	1	1	—	1	—	—
Salute	—	—	1	—	1	—	—
Sonalan	1	1	—	—	1	—	1
Trifluralin	1	1	1	1	1	—	1
Preplant-Incorporated or Preemergence							
Dual	1,2	1,2	1,2	1,2	1	2	1,2
Micro Tech	1,2	1,2	1,2	1,2	1	2	1,2
Prowl	1,2	1,2	1,2	1,2	1	2	1,2

1 = preplant incorporated, 2 = preemergence, and — = not registered.
[a] Only in Scepter label's "southern use area."

Table 11. Soybean Soil- and Foliar-Applied Herbicides: Grass and Nutsedge Control

											Perennials			
Herbicide	BYG	CBG	FLP	GFT	YFT	WCG	SBR	SHC	VCN	VCL	JHG	QKG	WSM	YNS
Soil-applied "grass"														
Command	9	9	9	9	9	7	8	6+	5	9	2	0	0	3
Dual	8+	9	8+	9	9	7	7	5	0	3	0	0	0	7+
Micro Tech	8+	9	8	9	9	7	7	5	0	3	0	0	0	7
Prowl	9	9	9	9	9	9	8	7+	4	6	3	2	0	0
Pursuit	6	7	7	7	6	6	5	7	4	4	3	0	0	4
Sonalan	9	8	9	9	9	8	8	7	4	6	2	2	0	0
Trifluralin	9	9	9	9	9	9	8	8	5	6	3	2	0	0
Foliar-applied postemergence														
Assure II	8+	9	9+	9+	8+	9	9	10	10	9	9	9	9	0
Fusilade	8+	8	8	8+	8	9	9	10	10	9	9	9	9	0
Fusion	8+	8	8+	9	8	9	9	10	10	9	9	9	9	0
Option II	8	7	8+	9	8	8	7	9	10	6	8	0	8	0
Poast Plus	9	8	9+	9+	9	9	7	8	8	7	7	7+	8	0
Pursuit	8	7	7	8	6	5	4	9	6	3	3	—	—	6
Select	9	8	9	9+	9	9	8	9	9	8	9	8	—	0

Annual grasses are BYG = barnyardgrass, CBG = crabgrass, FLP = fall panicum, GFT = giant foxtail, YFT = yellow foxtail, WCG = woolly cupgrass, SBR = sandbur, SHC = shattercane, VCN = volunteer corn, VCL = volunteer cereal (wheat, oats, rye), JHG = johnsongrass, QKG = quackgrass, WSM = wirestem muhly, and YNS = yellow nutsedge.

Rating Scale:
10 = 95 to 100 percent, 9 = 85 to 95 percent, 8 = 75 to 85 percent, 7 = 65 to 75 percent, 6 = 55 to 65 percent, and 5 = 45 to 55 percent.

Table 12. Soybean Soil-Applied Herbicides: Broadleaf Control

Herbicide	AMG	BCC	CCB	JMW	LBQ	BNS	PGW	CRW	GRW	SMW	SFR	PSI	VLV	SBN
Soil-applied "grass"														
Command	0	5	6	8	9	6	6	8	6	8	6	8	9+	1
Dual	0	0	0	4	6	7+	8	5	0	4	0	3	0	1
Micro Tech	0	0	0	5	7	7+	9	5	0	5	0	3	0	1
Prowl	4	0	0	2	9	0	9	2	0	4	0	0	6	1
Sonalan	4	0	0	2	9	6	9	2	0	4	0	0	3	2
Trifluralin	4	0	0	2	9	0	9	2	0	4	0	0	2	1
Soil-applied "broadleaf"														
Canopy	6	7	9	9	9	4	9	9	7	9	8	8	9	2
Lexone	3	2	6	7	9	3	9	8	5	9	7	8	8	2
Lorox	4	2	6	5	9	6	9	8	5	8	6	6	6	2
Lorox Plus	6	6	8	7	9	6	9	9	7	9	7	7	7	2
Preview	6	6	8	9	9	4	9	9	7	9	8	8	9	2
Pursuit	6	7	7	7	8	8	9	7	6	9	8	8	8	1
Scepter	6+	8	9	8	9	8+	9	8+	7	9	9	8	7	1+
Sencor	3	2	6	7	9	3	9	8	5	9	7	8	8	2

AMG = annual morningglory, BCC = burcucumber, CCB = cocklebur, JMW = jimsonweed, LBQ = lambsquarters, BNS = black nightshade, PGW = pigweed, CRW = common ragweed, GRW = giant ragweed, SMW = smartweed, SFR = wild sunflower, PSI = prickly sida, VLV = velvetleaf, and SBN = soybean tolerance.

Rating Scale and Approximate Weed Control
10 = 95 to 100 percent, 9 = 85 to 95 percent, 8 = 75 to 85 percent, 7 = 65 to 75 percent, and 6 = 55 to 65 percent.
Weed control of 5 or less is rarely significant.
For ratings for combinations (tank-mix and premix), see the component parts.

Premix	"Grass"	+	"Grass"
Commence:	Treflan	+	Command
Freedom:	Lasso	+	Treflan

Premix	"Grass"	+	"Broadleaf"
Passport:	Treflan	+	Pursuit
Pursuit Plus:	Prowl	+	Pursuit
Salute:	Treflan	+	Sencor
Squadron:	Prowl	+	Scepter
Tornado:	Fusilade	+	Reflex
Tri-Scept:	Treflan	+	Scepter
Turbo:	Dual	+	Sencor

Table 13. Soybean Postemergence Herbicides: Broadleaf Weed Control

Herbicide	AMG	BCC	CCB	JMW	LBQ	BNS	PGW	CRW	GRW	SMW	SFR	PSI	VLV	SBN
Contact postemergence														
Basagran	5	5	9+	9	7	3	4	7	8	9	8	8	8+	0
Blazer	8	7	7	9	5	8	9+	9	8	9	7	2	6	2
Galaxy	6	5	9	9	6	6	8	8	8	9	8	7	8+	1
Storm	7	6	8+	9	5	7	9	9	8	9	8	6	7+	1+
Cobra	8	8	8	9	4	8	9+	9	8	6	8	6	7	3
Reflex	7	6	7	9	5	7	9	8	7	7	7	2	6	1
Systemic postemergence														
Classic	7	8	9	8+	2	0	8	8	7	8	9	4	8+	1+
Pinnacle	4	2	6	4	8+	0	8+	5	4	8	6	4	8+	2
Classic and Pinnacle	6	6	9+	7	8+	0	8+	6	5	8	8	4	8+	2
Pursuit	7	8	8+	7	5	9+	9	7	7	8+	9	6	8+	1+
Scepter	3	6	9+	4	4	5	10	5	3	6	7	2	3	1

AMG = annual morningglory, BCC = burcucumber, CCB = cocklebur, JMW = jimsonweed, LBQ = lambsquarters, BNS = black nightshade, PGW = pigweed, CRW = common ragweed, GRW = giant ragweed, SMW = smartweed, SFR = wild sunflower, PSI = prickly sida, VLV = velvetleaf, and SBN = soybean response.

Rating Scale:
10 = 95 to 100 percent, 9 = 85 to 95 percent, 8 = 75 to 85 percent, 7 = 65 to 75 percent, 6 = 55 to 65 percent, and 5 = 45 to 55 percent.

Table 14. Postemergence Contact Herbicide Rates for Weed Heights or Growth Stages in Soybeans

	Basagran		Blazer		Galaxy		Storm		Cobra		Reflex	
Weed	Height	Rate	Height	Rate	Height	Rate	Height	Rate	Stage	Rate	Stage	Rate
	in.	*pt/A*	*in.*	*pt/A*	*in.*	*pt/A*	*in.*	*pt/A*	*leaves*	*fl oz/A*	*leaves*	*pt/A*
AMG	...	...	2 4	1.0 1.5	2	2	2	1.5	2	12.5	2 to 4	1.25[a]
CCB	4 6 10	1 1.5 2	2	1.5	6	2	6	1.5	6	12.5	2	1.25[a]
JMW	4 6 10	1 1.5 2	4 6	1.0 1.5	6	2	6	1.5	4	12.5	4 6	1.00 1.25[a]
LBQ[b]	1 2	1 2	2	1.5	2	2	2	1.5	...	...	2	1.00
BNS	...	...	<2 2	1.0 1.5	<2	2	2	1.5	6	12.5	4 6	1.00 1.25[a]
PGW	...	...	<4 4	1.0 1.5	2	2	2 to 3	1.5	6	12.5	4 6	1.00 1.25[a]
CRW	3	2	2 3	1.0 1.5	3	2	3	1.5	6	12.5	4 6	1.00 1.25[a]
GRW	6	2	<2 3	1.0 1.5	6	2	6	1.5	4	12.5	...	...
SMW	4 6 10	1.0 1.5 2	4 6	1.0 1.5	6	2	6	1.5	...	...	4 6	1.00 1.25[a]
SFR	3 5 8	1 1.5 2	...	...	5	2	...	...	2	12.5	...	...
PSI	3 4	1.5 2	...	...	3	2	2	1.5	4	12.5	...	...
VLV	2 5	1.5 2	...	...	5	2	2	1.5	4	12.5	...	...
YNS[c]	6 8	1.5 2	...	...	...	...	...	...	...	...	...	...

AMG = annual morningglory, CCB = common cocklebur, JMW = jimsonweed, LBQ = lambsquarters, BNS = black nightshade, PGW = pigweed, CRW = common ragweed, GRW = giant ragweed, SMW = smartweed, SFR = common sunflower, PSI = prickly sida, VLV = velvetleaf, YNS = yellow nutsedge.
[a] Reflex at 1.25 pints per acre to be applied south of I-70 only.
[b] Control of lambsquarters is often inconsistent with contact herbicides.
[c] May need to repeat application for complete control.

Table 15. Postemergence Translocated Herbicide Rates for Broadleaf Weed Heights in Soybeans

	Classic		Pinnacle		Classic + Pinnacle		Pursuit		Scepter	
Weed	Height	Rate	Height	Rate	Height	Rate of each	Height	Rate	Height	Rate
	in.	*oz/A*	*in.*	*oz/A*	*in.*	*oz/A*	*in.*	*fl oz/A*	*in.*	*pt/A*[a]
AMG	2 3 4	0.50 0.66 0.75	...	...	1 to 2[b]	0.25	1 to 2	4	...	...
CCB	6 8 12	0.50 0.66 0.75	2 to 6[b]	0.25	2 to 4	0.25	1 to 8	4	1 to 8 9 to 12	0.33 0.66
JMW	4 6	0.50 0.75	2 to 4[b]	0.25	2 to 5	0.25	1 to 3	4	...	...
LBQ	...	...	2 to 4	0.25	2 to 4	0.25	1 to 2	4	...	...
BNS	...	...	...	...	...	...	1 to 3	4	...	...
PGW	2 3 4	0.50[c] 0.66[c] 0.75[c]	2 to 12	0.25	2 to 12	0.25	1 to 8	4	1 to 4 5 to 12	0.33 0.66
CRW	3 4	0.66 0.75	...	...	1 to 3[b]	0.25	1 to 3	4	...	...
GRW	6	0.75	...	...	...	...	1 to 3	4	...	...
SMW	2 3 4	0.50 0.66 0.75	2 to 6	0.25	2 to 8	0.25	1 to 3	4	...	...
SFR	5 6 8	0.50 0.66 0.75	2 to 6[b]	0.25	2 to 8	0.25	1 to 3	4	1 to 4 5 to 8	0.33 0.66
VLV	4 6	0.66 0.75	2 to 6	0.25	2 to 8	0.25	1 to 3	4	...	...
YNS	3 4	0.50 0.75	...	...	...	...	1 to 3	4	...	...

AMG = annual morningglory, CCB = common cocklebur, JMW = jimsonweed, LBQ = lambsquarters, BNS = black nightshade, PGW = pigweed, CRW = common ragweed, GRW = giant ragweed, SMW = smartweed, SFR = common sunflower, VLV = velvetleaf, YNS = yellow nutsedge, ... = not on label.
[a] Or equivalent rates of 70DG formulation.
[b] Suppression only.
[c] Redroot pigweed only, smooth pigweed and tall waterhemp only suppressed.

Table 16. Postemergence Herbicide Tank-Mixes for Soybeans

	Basagran	Blazer	Galaxy	Reflex	Cobra	Classic	Pursuit
Registered for broadleaf weed control in soybeans							
Basagran	—	X	—	X	X	X	X
Classic	X	X	X	X	X	—	—
Scepter	X	X	—	X	X	—	—
Pinnacle	X	—	X	—	—	X	—
2,4-DB	X	X	X	X	X	X	—
Registered for grass + broadleaf weed control in soybeans[a]							
Assure II	X	—	—	—	X	X	X[b]
Fusilade	X	X	—	X	X	X	X[b]
Fusion	X	X	X	X	X	X	—
Option II	X	X	—	X	—	X	X[b]
Poast Plus	X	X	X	X	—	X	X
Pursuit	X	X	X	X	X	—	—
Select	X	X	—	X	—	X	X

X = registered and — = not registered.
[a] Check labels for special instructions. Sequential application may be preferable.
[b] To improve volunteer corn and shattercane control only.

Table 17. Application Rates and Grass Size for Treatment with Postemergence Herbicides for Soybeans

Grass Weed	Assure II		Fusilade 2000		Poast Plus		Option II		Fusion		Select	
	Height	Rate	Height	Rate	Height	Rate	Height	Rate	Height	Rate	Height	Rate
	in.	*fl oz/A*	*in.*	*fl oz/A*	*in.*	*fl oz/A*	*in.*	*pt/A*	*in.*	*fl oz/A*	*in.*	*fl oz/A*
Annuals												
Barnyardgrass	2 to 6	8	2 to 3	24	1 to 4 Up to 8	18 24	1 to 3 3 to 6	0.6 0.8	2 to 3	8	2 to 6	8
Crabgrass[a]	2 to 6	8	1 to 2	24	Up to 6	24	1 to 2 2 to 6	0.8 1.1	1 to 2	8	2 to 6	8
Fall panicum	2 to 6	7	2 to 6	24	1 to 4 Up to 8	18 24	1 to 3 3 to 6	0.6 0.8	2 to 6	8	2 to 6	8
Giant foxtail	2 to 8	7	2 to 6	24	1 to 4 Up to 8	18 24	1 to 3 3 to 6	0.4 0.6	2 to 6	8	2 to 6	8
Yellow foxtail	2 to 4	7	2 to 4	24	Up to 8	24	1 to 2 2 to 6	0.6 0.8	2 to 4	8	2 to 6	8
Woolly cupgrass	2 to 4	7	2 to 4	24	Up to 8	24	1 to 3 3 to 6	0.8 1.1	2 to 4	8	2 to 6	8
Sandbur	2 to 6	7	2 to 6	24	Up to 3	30	...	...	2 to 6	8	2 to 6	8
Shattercane	6 to 12	5	6 to 12	12[b]	6 to 18	24	2 to 6 6 to 12	0.4 0.6	6 to 12	6	4 to 10	8
Volunteer corn	6 to 18	5	12 to 24	12[b]	1 to 12 12 to 20	18 24	2 to 10 10 to 24	0.4 0.6	12 to 24	6	4 to 18	8
Volunteer cereal	2 to 6	7	2 to 6	16	Up to 4	36	...	...	2 to 6	8	2 to 6	8
Downy brome	...	...	2 to 6	16	...	...	...	...	2 to 6	6		
Perennials												
Johnsongrass (seedling)	2 to 8	5	2 to 8	12[b]	Up to 8	24	2 to 6 6 to 12	0.4 0.6	2 to 8	6	4 to 10	8
Johnsongrass (1st appl.)	10 to 24	10	8 to 18	24	15 to 25	24	10 to 20	1.0	...	...	12 to 24	10
Regrowth (2nd appl.)	6 to 10	7	6 to 12	16	6 to 12	24	10 to 20	0.5	...	...	6 to 10	8
Quackgrass (1st appl.)	6 to 10	10	6 to 10	24	6 to 8	36	...	...	6 to 10	12	4 to 8	16
Regrowth (2nd appl.)	4 to 8	7	10	16	6 to 8	24	...	...	10	8	4 to 8	16
Wirestem muhly (1st appl.)	4 to 8	8	4 to 12	24	Up to 6	30	1 to 2	0.8	4 to 12	8	...	...
Regrowth (2nd appl.)	4 to 8	7	4 to 12	24	Up to 6	30	2 to 6	1.1	4 to 12	8	...	...

[a] Crabgrass: length of lateral growth, not height.
[b] Use 16 ounces if drouthy or when tank-mixing with broadleaf herbicides.

Table 18. Problem Perennial Weeds

Weed	Crop	Herbicide	Remarks
Bindweed	Corn	2,4-D ester 0.5 pt/A or amine 1 pt/A of 3.8 a.e.[a]	Apply in spring when leaves are fully expanded or apply preharvest after brown silk stage in corn. The ester formulation is preferred. Use drop nozzles when corn is over 8 inches tall.
		Banvel 0.5 to 1 pt/A	Use the 0.5 pt rate of Banvel on sandy soils and on corn taller than 8 inches and up to 2 weeks before tasseling.
	Soybeans	Blazer, Cobra, Basagran (rates on label)	Vines may be suppressed by applications. Control can be improved by adding 2 fluid ounces/A of Butyrac 200.
Bigroot morningglory	Corn	2,4-D amine 1 pt/A or ester 0.5 pt/A of 3.8 a.e.	Use on actively growing plants that have sufficient vine growth (10 to 24 inches) to which the herbicide can be applied.
Canada thistle	Corn	Banvel 0.5 to 1 pt/A or 2,4-D amine 1 pt/A or ester 0.5 pt/A of 3.8 a.e.	Use the 0.5 pt rate of Banvel on sandy soils and on corn taller than 8 inches. Do not apply Banvel within 2 weeks of tasseling. Use drop nozzles when corn is over 8 inches tall.
		Laddok 3.5 pt/A	Suppression only. Apply when Canada thistle is 8 to 10 inches tall. Use with 2 pt/A COC.
		Buctril 1.5 pt/A or Buctril + Atrazine 2 to 3 pt/A	Suppression only. Apply to weeds from 8 inches tall to the bud stage or up to tassel emergence on corn. Do not add spray additives. Apply before corn is 12 inches. May be combined with Stinger.
		Stinger ⅓ to ⅔ pt/A	Apply as broadcast spray from 4-inch rosette to before bud stage. Do not apply after the corn is 24 inches tall; do not apply more than ⅔ pt/A per year.
	Corn/Soybeans	Roundup 2 to 3 qt/A	Apply after harvest and prior to tillage in the fall. Do not till for 3 days after application. Weeds should be actively growing.
		Basagran 1 qt/A	Will suppress thistle growth. Retreatment 7 to 14 days later with Basagran, or cultivation may be necessary to maintain suppression.
Common milkweed and hemp dogbane	Corn	2,4-D amine 1 to 2 pt/A or ester 1 to 2 pt/A of 3.8 a.e.	Apply mid- to late-season after corn silks have turned brown and plants are actively growing and have adequate foliage.
	Soybeans	Blazer, Cobra (rates on label)	Suppresses common milkweed but not hemp dogbane.
		Roundup 33% solution; 1 gal Roundup with 2 gal water	Apply with wiper applicator (ropewick or sponge) used above crop.
Honeyvine milkweed	Corn	2,4-D ester 0.5 pt/A or 2,4-D amine 1 pt/A of 3.8 a.e. or Banvel 0.5 to 1 pt/A or 2,4-D + Banvel at half rates	The ester formulation of 2,4-D is preferred; however, a combination of 2,4-D and Banvel may be better than 2,4-D used alone. Check Banvel label for restrictions.
Jerusalem artichoke	Corn	Banvel 0.5 to 1 pt/A or Banvel + 2,4-D at half rates	Treat weeds when they are 8 to 16 inches tall. Use the 0.5 pt rate of Banvel on sandy soils and on corn taller than 8 inches and up to 2 weeks before tasseling. Use drop nozzles when corn is over 8 inches tall.
		Stinger ¼ to ½ pt/A	Apply up to the 5-leaf stage. Do not apply more than ⅔ pt/A per year if retreatment is necessary. Do not apply to corn taller than 24 inches.
		Beacon ¾ oz/A	Apply to 1- to 4-inch artichoke.
	Soybeans	Pursuit 4 fluid oz/A or Classic 0.75 oz/A	Pursuit should be applied to plants that are 6 to 8 inches tall and Classic to plants less than 8 inches tall. Small weeds just emerging may have sufficient root or tuber reserves to begin regrowth after treatment and a cultivation may be required. Use a surfactant at 0.25 percent, or 1 qt in 100 gallons of spray.

Table 18. Problem Perennial Weeds (cont.)

Weed	Crop	Herbicide	Remarks
Swamp smartweed	Corn	Banvel 0.5 to 1 pt/A	Use the higher rate on corn shorter than 8 inches. Use the lower rate on taller corn up to 36 inches or up to 2 weeks before tasseling, whichever comes first, or on sandy soils. Use drop nozzles if the corn is more than 8 inches tall.
		Stinger ¼ to ½ pt/A	Suppression only. Apply to weed at 2- to 3-leaf stage. Do not apply after corn is 24 inches. Do not apply more than ⅔ pt/A per year.
	Corn/soybeans	Roundup 3 to 5 qt/A; see label for low-rate technology.	Apply before spring tillage or after harvest. Allow at least 7 days before tillage.
Yellow nutsedge	Corn	Sutan+, Eradicane (labeled rate for soil)	Apply preplant-incorporated.
		Laddok 3.5 pt/A	Suppression only. Add 2 pt/A COC.
	Corn/Soybeans	Lasso, Dual	Use higher rate for soil type and incorporate thoroughly.
		Basagran 2 pt/A	Apply 1.5 to 2 pt/A when plants are 6 to 8 inches tall. Reapply 7 to 10 days later if needed. Add 2 pt/A COC with each application.
	Soybeans	Scepter 0.6 pt/A or Pursuit 0.25 pt/A	Thoroughly incorporate for best control.
		Classic 0.5 oz to ¾ oz/A	Apply Classic at the 4- to 6-leaf stage. Use a nonionic surfactant at 1 qt per 100 gallons of spray.
Rhizome or seedling johnsongrass	Corn	Accent ⅔ oz/A	Apply to 4- to 10-inch tall seedling johnsongrass, or apply up to 1⅓ oz (in split application) on rhizome johnsongrass 8 to 12 inches tall. Use a nonionic surfactant at 1 qt per 100 gallons of spray or COC at 4 qts per 100 gallons of spray. See label for restrictions.
		Beacon ¾ oz/A as a single or split application	Apply to seedling johnsongrass when 4 to 12 inches tall and rhizome johnsongrass when 8 to 16 inches tall. Add nonionic surfactant at 1 qt per 100 gallons of spray or COC at 1 to 4 pts/A. See label for restrictions.
	Soybeans	Assure II 10 fl oz/A	Apply to johnsongrass when 10 to 24 inches tall. Apply additional 7 fl oz to regrowth 6 to 10 inches tall if needed.
		Poast Plus 1.5 pt/A	Apply to johnsongrass 15 to 25 inches tall. Use Dash or COC. Treat 6- to 12-inch regrowth with same rate.
		Select 8 fl oz/A	Apply to johnsongrass 12 to 24 inches tall. Apply 6 fl oz/A to regrowth if needed.
		Fusilade 1.5 pt/A	Apply to 8- to 18-inch johnsongrass. Retreat 6- to 12-inch regrowth at 1 pt/A. Use COC or nonionic surfactant.
		Option II 1.0 pt/A	Apply to 10- to 20-inch johnsongrass. *Do not add COC.* Apply 0.5 pt/A to regrowth.
		Roundup 33% solution; 1 gal Roundup with 2 gal water	Apply with wiper application (ropewick or sponge) used above crop.
Quackgrass	Corn	Accent ⅔ oz/A	Apply to 2- to 4-inch tall quackgrass or apply up to 1⅓ oz (in split application) on quackgrass up to 6 inches tall. Use a nonionic surfactant at 1 qt or COC at 4 qts per 100 gallons of spray. See label for restrictions.
		Beacon ¾ oz/A	Apply to quackgrass when 4 to 8 inches tall. Control of this species is not immediate and symptoms may take several days to develop. Add nonionic surfactant at 1 qt per 100 gallons of spray or COC at 1 to 4 pts/A. See label for restrictions.
		Eradicane Extra 4 qt/A or Eradicane 6.7E 7.3 pt/A	A lower rate may be used on lighter infestations. Use a tank-mix with atrazine to improve control.

Table 18. Problem Perennial Weeds (cont.)

Weed	Crop	Herbicide	Remarks
Quackgrass (cont.)	Corn/Soybeans	Roundup 1 to 2 qt/A	Apply prior to spring tillage or after harvest in the fall. Do not till for 3 days before or after application. Weeds should be actively growing and greater than 8 inches tall.
	Soybeans	Assure II 10 fl oz/A	Apply when quackgrass is 6 to 10 inches tall. For regrowth apply 7 fl oz/A when quackgrass is 4 to 8 inches tall. Add COC at 2 pt/A.
		Fusilade 1.5 pt/A	Apply to 6- to 10-inch quackgrass. For regrowth, apply 1 pt/A to quackgrass up to 10 inches tall. Use COC or nonionic surfactant.
		Fusion 12 fl oz/A	Apply to quackgrass that is 6 to 10 inches tall. Treat regrowth (up to 10 inches) with 8 fl oz/A.
		Poast Plus 2.25 pt/A	Apply to quackgrass 6 to 8 inches tall and retreat at 1.5 pt/A for regrowth. Use Dash or COC at 2 pt/A.
		Select 1 pt/A	Apply to quackgrass 4 to 8 inches tall and retreat regrowth at the same rate and size if needed. Add COC at 2 pt/A.
Wirestem muhly	Soybeans	Assure II 8 fl oz/A	Apply when wirestem muhly is 4 to 8 inches tall. For regrowth, apply 7 fl oz/A. Add COC at 2 pt/A.
		Fusilade 1.5 pt/A	Apply to 4- to 12-inch wirestem muhly. Apply to regrowth at the same size and rate. Use COC or nonionic surfactant.
		Fusion 12 fl oz/A	Apply to wirestem muhly that is 4 to 12 inches tall. Treat regrowth up to 10 inches tall with 8 fl oz/A. Add COC or nonionic surfactant.
		Poast Plus 2.25 pt/A	Apply to wirestem muhly up to 6 inches tall. Retreat at same rate and size for regrowth. Use Dash or COC.
		Option II 1.1 pt/A	Apply to 3- to 6-inch wirestem muhly. Use COC or nonionic surfactant.

[a] a.e. = acid equivalent. If not 3.8 lb/gal, use equivalent amount.

4 Weed Control for Small Grains, Pastures, and Forages

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Good weed control is necessary for maximum production of high-quality small grains, pastures, and forages in Illinois. When properly established, these crops can usually compete effectively with weeds so the need for herbicide applications is minimized. However, weeds can sometimes become significant problems and warrant control. For example, wild garlic is considered the worst weed problem in wheat in southern Illinois. Because its life cycle is similar to that of winter wheat, wild garlic can establish itself with the wheat, grow to maturity, and produce large quantities of bulblets by wheat-harvest time. Economic considerations often make it necessary to control wild garlic in winter wheat to minimize dockage.

In pastures, woody and herbaceous perennials can become troublesome. Annual grasses and broadleaf weeds such as chickweed and henbit may cause problems in hay crops. Through proper management, many of these weed problems can be controlled effectively.

Several herbicide labels carry the following groundwater warnings under either the enviromental hazard or the groundwater advisory section: "X is a chemical that can travel (seep or leach) through soil and enter groundwater which may be used as drinking water. X has been found in groundwater as a result of its use as a herbicide. Users of this product are advised not to apply X where the soils are very permeable (that is, well-drained soils such as loamy sands) and the water table is close to the surface." See Table 1 for a list of herbicides that carry this warning. A few labels also warn against contamination of surface water.

Small Grains

Good weed control is critical for maximum production of high-quality small grains. Often, problems with weeds can be dealt with before the crop is established. For example, some broadleaf weeds can be controlled effectively in the late fall with **2,4-D, Banvel** (dicamba), or **Roundup** (glyphosate) after corn or soybean has been harvested, if seeding is not too late.

Tillage helps control weeds. Although generally limited to preplant or postharvest operations, tillage can destroy many annual weeds and help suppress certain perennials. Good cultural practices such as proper seeding rate, optimum soil fertility, and timely planting help to ensure the establishment of an excellent stand and a crop that is better able to compete with weeds.

Winter annual grasses such as downy brome and cheat are very competitive in winter wheat. Illinois wheat producers are often limited to preplant tillage operations for control of these species, as few herbicides have label clearances for annual grass control in winter wheat. If a severe infestation of downy brome or cheat exists, planting an alternative crop or spring crop may be best for that field.

A decision to use postemergence herbicides for broadleaf weed control in small grains should be based on several considerations:

1. *Nature of the weed problem.* Identify the species present and consider the severity of the infestation. Also note the size of the weeds. Weeds are usually best controlled while small.

2. *Stage of the crop.* Most herbicides are applied after full tiller until the boot stage. Do not apply herbicides from the boot stage to the hard-dough stage of most small grains. (See Figure 1 for a description of growth stages of small grains.)

3. *Herbicide activity.* Determine crop tolerance and weed susceptibility to herbicides by referring to Tables 2 and 3. The lower rates in Table 3 are for more easily controlled weeds and the higher rates for the more difficult-to-control species. Tank-mixes may broaden the weed spectrum and thereby im-

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The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

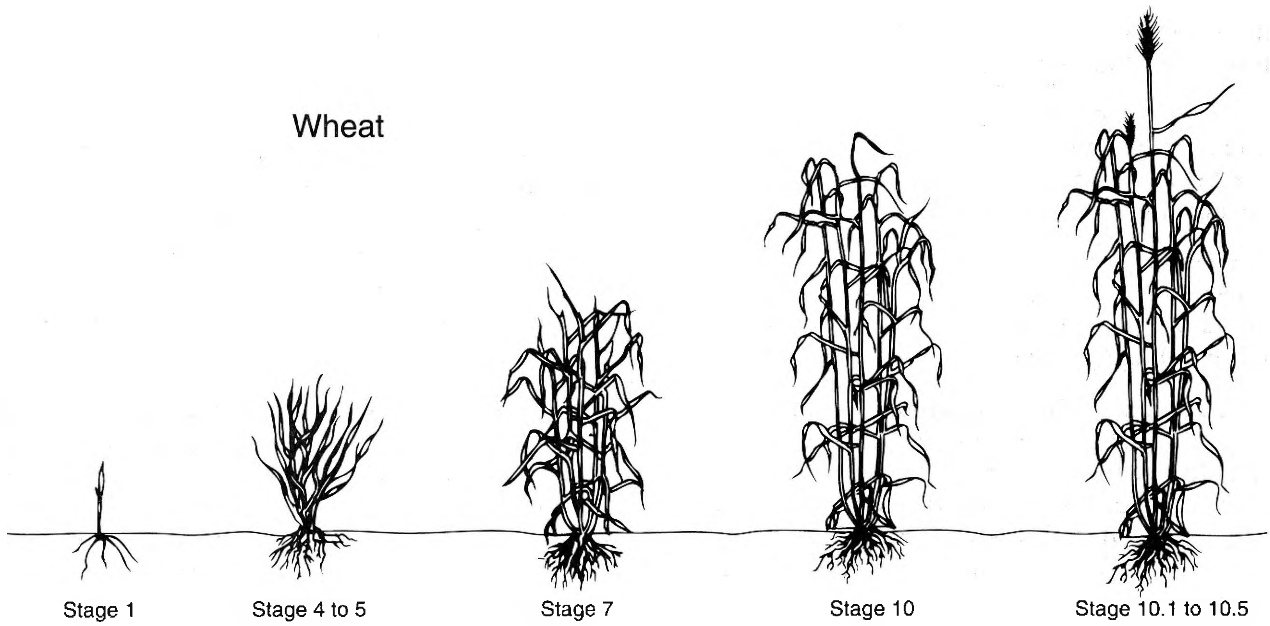

Figure 1. Growth stages of small grains.

Seedling

Stage 1. The coleoptile, a protective sheath that surrounds the shoot, emerges. The first leaf emerges through the coleoptile, and other leaves follow in succession from within the sheath of the previously emerging leaf.

Tillering

Stages 2 to 3. Tillers (shoots) emerge on opposite sides of the plant from buds in the axils of the first and second leaves. The next tillers may arise from the first shoot at a point above the first and second tillers or from the tillers themselves. This process is repeated until a plant has several shoots.

Stages 4 to 5. Leaf sheaths lengthen, giving the appearance of a stem. The true stems in both the main shoot and in the tillers are short and concealed within the leaf sheaths.

Jointing

Stage 6. The stems and leaf sheaths begin to elongate rapidly, and the first node (joint) of the stem is visible at the base of the shoot.

Stage 7. Second node (joint) of stem is visible. The next-to-last leaf is emerging from within the sheath of the previous leaf but is barely visible.

Stage 8. Last leaf, the "flag leaf," is visible but still rolled.

Stage 9: Preboot stage. Ligule of flag leaf is visible. The head begins to enlarge within the sheath.

Stage 10: Boot stage. Sheath of flag leaf is completely emerged and distended because of enlarging but not yet visible head.

Heading

Stages 10.1 to 10.5. Heads of the main stem usually emerge first, followed in turn by heads of tillers in order of their development. Heading continues until all heads are out of their sheaths. The uppermost internode continues to lengthen until the head is raised several inches above the uppermost leaf sheath.

Flowering

Stages 10.5.1 to 10.5.3. Flowering progresses in order of head emergence. Unpollinated flowers result in barren kernels.

Stage 10.5.4: Premilk stage. Flowering is complete. The inner fluid is abundant and clear in the developing kernels of the flowers pollinated first.

Ripening

Stage 11.1: Milk stage. Kernel fluid is milky white because of accumulating starch.

Stage 11.2: Dough stage. Kernel contents are soft and dry (doughy) as starch accumulation continues. The plant leaves and stems are yellow.

Stage 11.3. The kernel is hard, difficult to divide with the thumbnail.

Stage 11.4. Ripe for cutting. Kernel will fragment when crushed. The plant is dry and brittle.

prove control; check the herbicide label for registered combinations.

4. *Presence of a legume underseeding.* Usually 2,4-D ester formulations and certain other herbicides listed in Table 3 should not be applied because they may damage the legume underseeding.

5. *Economic justification.* Consider the treatment cost in terms of potential benefits such as the value of increased yield, improved quality of grain, and ease of harvesting the crop.

Table 3 outlines current suggestions for weed control options in wheat and oats, the two small grains most commonly grown in Illinois. Please refer to Table 4 for grazing restriction information concerning herbicides used in small grains. Always consult the herbicide label for specific information about the use of a given product.

For annual broadleaf weeds, postemergence herbicides such as **2,4-D, MCPA, Banvel,** and **Buctril** (bromoxynil) can provide good control of susceptible species (Table 2). Herbicides must be applied during certain growth stages of the crop to avoid crop injury and for optimum weed control. Refer to Figure 1 for a description of the growth stages of small grains.

Some perennial broadleaf weeds may not be controlled satisfactorily with the low herbicide rates used in small grains, and higher rates are not advisable because they can cause serious injury to crops. To control perennial weeds, translocated herbicides such as **2,4-D, Banvel,** or **Roundup,** in combination with tillage after small grain harvest or after soybean harvest but before establishing small grains, may be the best approach.

Stinger (clopyralid) may be used to control broadleaf weeds in wheat, oats, and barley. Stinger controls Canada thistle as well as a number of annual broadleaf weeds (Table 2).

Wild garlic continues to be a serious weed problem in winter wheat. **Harmony Extra** (thifensulfuron + tribenuron), applied in the spring at 0.3 to 0.6 ounce of 75DF per acre, effectively controls wild garlic aerial bulblets and some underground bulbs as well. Harmony Extra also helps control chickweed, henbit, common lambsquarters, smartweed, and several species of mustard. See Tables 2 and 3 for additional information on controlling weeds in small grains.

Grass Pastures

Unless properly managed, broadleaf weeds can become a serious problem in grass pastures. They can compete directly with forage grasses and reduce the nutritional value and longevity of the pasture. Certain species, such as white snakeroot and poison hemlock, are also poisonous to livestock and may require special consideration.

Perennial weeds are of great concern in pasture management. They can exist for many years, reproducing from both seed and underground parent rootstocks. Occasional mowing or grazing helps control certain annual weeds, but perennials can grow back from underground root reserves unless long-term control strategies are implemented.

Certain biennials can also flourish in grass pastures. The first year they exist as a prostrate rosette, so that even close mowing does little to control their growth. The second year, biennials produce a seedstalk and a deep taproot. If these weeds are grazed or mowed at this stage, root reserves can enable the plant to grow again, thereby increasing its chance of surviving to maturity.

In general, the use of good cultural practices such as maintaining optimum soil fertility, rotational grazing, and periodic mowing can help keep grass pastures in good condition and more competitive with weeds. Where broadleaf weeds become troublesome, however, **2,4-D, Banvel,** or **Stinger** may be used. **Roundup** may also be used as a spot treatment, and **Crossbow** (2,4-D plus triclopyr) or **Ally** (metsulfuron methyl) are labeled for control of broadleaf and woody plant species in grass pastures. **Spike 20P** (tebuthiuron) may also be used in grass pastures for brush and woody plant control. (See Tables 5 and 6 for additional information.)

Proper identification of target weed species is important. As shown in Table 5, weeds vary in their susceptibility to herbicides. Timing of herbicide application may also affect the degree of weed control. Annuals and biennials are most easily controlled while young and relatively small. A fall or early spring treatment works best if biennials or winter annuals are the main weed problem. Summer annuals are most easily controlled in the spring or early summer. Apply translocated herbicides to control established perennials when the weeds are in the bud to bloom stage. Perennials are most susceptible at this reproductive phase because translocated herbicides can move downward with food reserves to the roots, thus killing the entire plant.

For control of woody brush, apply **2,4-D, Banvel,** or **Crossbow** when the plants are fully leafed and actively growing. Where regrowth occurs, a second treatment may be needed in the fall. During the dormant season, oil-soluble formulations of **2,4-D, Banvel** or **Crossbow** may be applied in fuel oil to the trunk. **Spike** controls many woody perennials and should be applied to the soil in the spring. Spike requires rainfall to move it into the root zone of target species. **Ally** as a spot treatment controls multiflora rose, Canada thistle, and blackberry (*Rubus spp.*) or suppresses these weeds and controls several annual broadleaf weeds when applied as a broadcast treatment at the lower rate range.

The weed control options in grass pastures are shown in Table 6. Refer to Table 7 for information concerning grazing restriction for herbicides used in grass pastures. Be cautious with any pesticide and always consult the herbicide label for specific information about the use of a given product.

Forage Legumes

Weed control is important in managing forage legumes. Weeds can reduce the vigor of legume stands, reducing yield and forage quality. Good management begins with weed control that prevents weeds from becoming serious problems.

Establishment

To minimize problems, prepare the seedbed properly so that it is firm and weed-free. Select an appropriate legume variety. If you use high-quality seed and follow the recommendations for liming and fertility, the legume crop may compete well with many weeds and reduce the need for herbicides.

In fields where companion crops such as oats are used to reduce weed competition, seed the small grain at half the rate for grain production to ensure that the legumes will become established with minimum stress. If the legume is seeded without a companion crop (direct-seeded), the use of an appropriate herbicide is suggested.

Preplant-Incorporated Herbicides

Balan (benefin) and **Eptam** (EPTC) are registered for preplant incorporation for legumes that are not seeded with grass or small-grain companion crops. These herbicides will control most annual grasses and some broadleaf weeds. In fall plantings, the weeds controlled include winter annuals such as downy brome and cheat. In spring legume plantings, the summer annual weeds controlled include foxtails, pigweeds, lambsquarters, crabgrass, and fall panicum. **Eptam** can help suppress johnsongrass, quackgrass, yellow nutsedge, and shattercane, in addition to controlling many annual grasses and some broadleaf weeds. Neither herbicide will effectively control mustards, smartweed, or established perennials.

Balan and **Eptam** *must* be thoroughly incorporated soon after application to avoid herbicide loss. They should be applied shortly before the legume is seeded so they remain effective as long as possible into the growing season.

Weeds that emerge during crop establishment should be evaluated for their potential to become problems. If they do not reduce the nutritional value of the forage or if they can be controlled by mowing, they should not be the primary target of a postemergence herbicide. For example, winter annual weeds do not compete vigorously with the crop after the first spring cutting. Unless they are unusually dense or production of weed seed becomes a concern, these weeds may not be a significant problem. Some weeds such as dandelions are palatable and may not need to be controlled if the overall legume stand is dense and healthy, but undesirable weeds must be controlled early to prevent their establishment.

Postemergence Herbicides

Poast Plus (sethoxydim) may be applied to seedling alfalfa for control of annual and some perennial grass weeds after weed emergence. Grasses are more easily controlled when small. **Butyrac** (2,4-DB) controls many broadleaf weeds and may be applied postemergence in many seedling forage legumes. **Buctril** (bromoxynil) may be used to control broadleaf weeds in seedling alfalfa. Be sure to apply Buctril while weeds are small, and use precautions to avoid an adverse effect on the crop. (See Table 8 for specific weed control ratings and Table 9 for rates and remarks.)

Established Legumes

The best weed control practice in established forage legumes is maintenance of a dense, healthy stand with proper management techniques. Chemical weed control in established forage legumes is often limited to late fall or early spring applications of herbicide. **Sencor** or **Lexone** (metribuzin), **Sinbar** (terbacil), and **Velpar** (hexazinone) are applied after the last cutting in the fall or in the early spring. These herbicides control many broadleaf weeds and some grasses, too. **Kerb** (pronamide) is used for grass control and is applied in the fall after the last cutting. The herbicide **2,4-DB** controls many broadleaf weeds in established alfalfa; it should be applied when the weeds are small and actively growing. Refer to Tables 8 and 9 for additional remarks and weed control suggestions.

Once grass weeds have emerged, they are particularly difficult to control in established alfalfa. **Poast Plus** herbicide may be used in established alfalfa for postemergence control of annual and some perennial grasses. Optimum grass control is achieved if Poast

Plus is applied when grasses are small and before the weeds are mowed.

Table 8 outlines current suggestions for weed control options in legume forages. The degree of control will often vary with weed size, application rate, and environmental conditions. Be sure to select the correct herbicide for the specific weeds to be controlled (Table 8). Refer to Table 10 for grazing and harvesting restrictions for forage legumes. Always consult the herbicide label for specific information about the use of a given product.

Acreage Conservation Reserve Program

Investing in good weed control on Acreage Conservation Reserve (ACR) land will help alleviate some problem weeds when rotating back to row crops. For example, perennial broadleaf weeds such as hemp dogbane and common milkweed may be controlled or suppressed in small-grain production or when a perennial grass or legume species is grown. In addition, mowing or alternative herbicide options may be available. Whether using tillage, mowing, herbicides, or combinations, the best approach is to remain flexible and use cost-effective methods that fit your weed problems and management system.

Clover, alfalfa, or other forage legumes may be one of the best options for ACR acres. The cover helps conserve soil, improves soil structure, and adds nitrogen. Clover and alfalfa can be quite economical, particularly if grown for at least two consecutive years. The use of a herbicide for legume establishment can allow a vigorous legume stand and alleviate the need for weed control measures later. If annual broadleaf weeds become a problem, consider applying **2,4-DB** or mowing. Herbicides for use on forage legumes on ACR acres include some of those registered for commercial production fields (Table 8). In addition, **Treflan** (trifluralin) or **Prowl** (pendimethalin) may be used preplant incorporated to control annual grasses and some small-seeded broadleaf weeds. Some stand reduction may occur with Treflan or Prowl, but good weed control can compensate to allow for good establishment of the legume. **Fusilade** (fluazifop), **Poast Plus** (sethoxydim) or **Option II** (fenoxaprop) may be used for grass control postemergence on some forage legumes on ACR land. With many of these products, haying and grazing are not allowed; therefore, be sure to follow all restrictions imposed by the pesticide label.

Oats are commonly grown as a cover crop on set-aside acres. Oat seed is inexpensive and easy to obtain. If the Agricultural Stabilization and Conservation Service (ASCS) does not require clipping before seed maturity, oats can reseed for fall cover. Wheat, rye, or barley are other small-grain cover crop possibilities.

Sowing clean small-grain seed is the first step toward minimizing weed problems. Small grains generally provide relatively good cover until they mature or the area is mowed; then weeds can soon proliferate. However, winter wheat or rye may be sown in the spring, and without the overwintering period (vernalization), little or no seed production occurs and a dense cover remains. Annual broadleaf weeds can be controlled by mowing and by the use of the herbicides listed in Table 3. Tilling before small-grain planting will help control established weeds.

Sorghum-sudan grass can make a rapid, vigorous cover that also effectively suppresses many weeds. Although herbicides are rarely needed in sorghum-sudan grass stands, mowing and tillage may be difficult, and viable seed sometimes causes weed problems the next year.

Planting a small-grain/legume combination is another option for set-aside. Using the small grain as a companion crop may help reduce weed pressure and alleviate the need for herbicides. If weeds become a problem, refer to Table 8 for more information in selecting the appropriate herbicide.

In addition to those herbicides listed in Table 8, **Buctril** may be used to control broadleaf weeds in seedling alfalfa-grass mixes on Conservation Reserve Program (CRP) acres. Refer to current label rates and restrictions.

Acreage Conservation Reserve land may offer an opportunity for controlling certain problem weeds, such as perennials, and may keep other, more common weeds in check. By managing ACR land this year, controlling weeds in future row crops will be less difficult and more economical.

Table 1. List of Herbicides, Formulations, and Special Statements

Trade name	Common name	Formulation	Restricted use	Groundwater advisory	Key word
Ally 60 DF	metsulfuron methyl	60%	—	—	Caution
Balan 1.5E	benefin	1.5 lb/gal	—	—	Danger
Banvel	dicamba	4 lb a.e.*/gal	—	—	Warning
Buctril	bromoxynil	2 lb/gal	—	—	Danger[a]
Butyrac 200	2,4-DB	2 lb a.e./gal	—	—	Caution
Butoxone 200	2,4-DB	2 lb a.e./gal	—	—	Caution
Crossbow	2,4-D + triclopyr	2 + 1 lb a.e./gal	—	—	Caution
Eptam 7E, 10G	EPTC	7 lb/gal, 10%	—	—	Caution
Fusilade 2000	fluazifop	1 lb a.e./gal	—	—	Caution
Gramoxone Extra	paraquat	2.5 lb/gal	Yes	—	Danger[a]
Harmony Extra 75DF	thifensulfuron + tribenuron	75%	—	—	Warning
Kerb 50W	pronamide	50%	Yes	—	Caution
Lexone 75DF	metribuzin	75%	—	Yes	Caution
MCPA	MCPA	several	—	—	Warning
Option II	fenoxaprop	0.79 lb a.e./gal	Yes	—	Danger[a]
Poast Plus	sethoxydim	1 lb/gal	—	—	Warning
Prowl	pendimethalin	3.3 lb/gal	—	—	Warning
Roundup	glyphosate	3 lb a.e./gal	—	—	Warning
Sencor 4L	metribuzin	4 lb/gal	—	Yes	Caution
Sencor 75DF	metribuzin	75%	—	Yes	Caution
Sinbar 80W	terbacil	80%	—	—	Caution
Spike 20P	tebuthiuron	20%	—	—	Warning
Stinger	clopyralid	3 lb a.e./gal	—	Yes	Caution
Treflan	trifluralin	4 lb/gal	—	—	Warning
Velpar L	hexazinone	2 lb/gal	—	—	Danger[a]
2,4-D amine	2,4-D	3.8 lb a.e./gal	—	—	Danger[a]
2,4-D ester	2,4-D	3.8 lb a.e./gal	—	—	Caution

* a.e. = Acid equivalent for these herbicides. All others are active ingredient (a.i.) formulations.
[a] Danger: Check label for safety equipment and precautions.

Table 2. Effectiveness of Herbicides on Weeds in Small Grains

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rate and weed size or growth stage. Performance may vary due to weather and soil conditions, or other variables.

Weed	Susceptibility to herbicide					
	2,4-D	MCPA	Banvel	Buctril	Harmony Extra	Stinger
Winter annual						
Buckwheat, wild	5	8	10	9	8	8
Chickweed, common	5	5	6	6	9	0
Henbit	5	5	6	8	9	0
Horseweed (marestail)	8	8	10	6	7	9
Lettuce, prickly	10	9	8	6	8	9
Mustard spp., annual	10	10	6	9	9	0
Pennycress, field	10	10	6	8	9	0
Shepherdspurse	10	10	8	8	9	0
Summer annual						
Lambsquarters, common	10	10	10	10	8	0
Pigweed spp.	10	10	10	7+	9	0
Ragweed, common	10	9	10	9	0	9
Ragweed, giant	10	9	10	8	0	10
Smartweed, Pennsylvania	6	7	9	9	9	6
Perennial						
Dandelion	9	8	8	0	6	9
Garlic, wild						
aerial bulblets	6[a]	5	5	0	9	0
underground bulbs	0	0	0	0	5	0
Thistle, Canada	7	7	8	6	7	9

[a] 2,4-D ester at maximum use rate.

Rating Scale:
10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, 6 = 55 to 65%, 5 = 45 to 55%, and 0 = less than 45% control or not labeled.

Table 3. Weed Control in Small Grains

Herbicide	Broadcast rate/acre	Remarks: See Table 4 for grazing restrictions.
Oats and wheat with legume underseeding		
2,4-D amine (3.8 lb a.e.)	½ to 1½ pt	Winter wheat more tolerant than oats. Apply in spring after full tiller but before boot stage. Do not treat in fall. Use lower rate if underseeded with legume. Some legume damage may occur. May be used as preharvest treatment at 1 to 2 pints per acre during hard-dough stage.
MCPA amine	¼ to 3 pt	Less likely than 2,4-D to damage oats and legume underseeding. Apply from 3-leaf stage to boot stage. Rate varies with crop and weed size and presence of legume underseeding.
Buctril 2E	1 to 2 pt	Apply Buctril alone to fall-seeded small grains in the fall or spring, but before the boot stage. Weeds are best controlled before the 3- to 4-leaf stage. Buctril may be applied at 1 to 1½ pints per acre to small grains underseeded with alfalfa.
Oats and wheat without legume underseeding		
Banvel, 4 lb a.e.	4 fl oz	*Do not use with legume underseeding.* In fall-seeded wheat, apply before jointing stage. In spring-seeded oats, apply before oats exceed 5-leaf stage.
Stinger 3 lb a.e.	¼ to ⅓ pt	*Do not use with legume underseeding.* Apply to small grains from the 3-leaf stage up to the early boot stage. For control of Canada thistle, ⅓ pint per acre should be used. For control of additional weeds, Buctril, Banvel, Harmony, MCPA, or 2,4-D may be tank-mixed with Stinger.
Wheat only		
2,4-D ester (3.8 lb a.e.)	½ to ¾ pt	*Do not use with legume underseeding.* Apply in spring after full tiller but before boot stage. For preharvest treatment, apply 1 to 2 pints per acre during hard-dough stage. For control of wild garlic or wild onion, apply 1 to 2 pints in the spring when wheat is 4 to 8 inches high, after tillering but before jointing; these rates may injure the crop.
Harmony Extra 75DF	0.3 to 0.6 oz	*Do not use with legume underseeding.* Apply to the crop after the 2-leaf stage, but before the flag leaf is visible. Wild garlic should be less than 12 inches tall, with 2 to 4 inches of new growth. Annual broadleaf weeds should be past the cotyledon stage, actively growing, and less than 4 inches tall or across. Nonionic surfactant at 0.25% v/v should be included in the spray mixture. When liquid fertilizer is used as the carrier, use $\frac{1}{16}$-¼% v/v surfactant. Temporary stunting and yellowing may occur when Harmony Extra is applied using liquid fertilizer solution as the carrier. These symptoms will be intensified with the addition of surfactant. Without surfactant addition, wild garlic control may be erratic. Do not plant any crop other than wheat or barley within 60 days after application.

Table 4. Small Grain Herbicides and Livestock Use

Herbicide name				Days after treatment before			
				Graze green			
Trade	Common	Crops[a]	Applied	Beef	Dairy	Feed straw	Withdraw for meat
Banvel	dicamba	WOB	Prejoint	No	No	Yes	0
Buctril	bromoxynil	WORBT	Preboot	30	30	30	30
Harmony Extra	2:1 mixture of thifensulfuron + tribenuron	WB	Before flagleaf	No	No	Yes	0
Many	2,4-D	WORB	Preboot	0	14	0	14
Many	2,4-D–late	WORB	Before harvest	No	No	No	. . .[b]
Many	MCPA	WORB	Prejoint	0	7	0	7
Stinger	clopyralid	WOB	Preboot	0	7	No	7

[a] Crops: W = wheat, O = oats, R = rye, B = barley, T = triticale.
[b] No grazing information available.

Table 5. Effectiveness of Herbicides on Weeds in Grass Pastures

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rate and weed size or growth stage. Performance may vary due to weather and soil conditions or other variables.

Weed	Susceptibility to herbicide					
	Ally	2,4-D	Banvel	Crossbow	Stinger	Roundup[a]
Winter annual						
Horseweed (marestail)	9	9	10	10	9	10
Pennycress, field	0	10	8	9	0	10
Summer annual						
Ragweed, common	0	10	10	10	9	10
Ragweed, giant	0	10	10	10	10	10
Biennial						
Burdock, common	0	10	10	10	8	9
Hemlock, poison	0	9	10	10	0	9
Thistle, bull	0	10	10	10	9	10
Thistle, musk	9	10	9	9	9	10
Perennial[b]						
Daisy, oxeye	0	8	10	10	9	9
Dandelion	0	10	8	10	9	8
Dock, curly	0	7	10	10	8	9
Goldenrod spp.	0	8	9	8	0	10
Hemlock, spotted water	0	9	10	10	0	9
Ironweed	0	8	10	9	0	10
Milkweed, common	0	6	8	8	0	8
Nettle, stinging	0	9	9	9	0	9
Plantain spp.	0	10	8	10	0	9
Rose, multiflora[c]	9	8	9	9	0	9
Snakeroot, white	0	8	9	9	0	8
Sorrel, red	0	5	10	10	6	8
Sowthistle, perennial	0	8	9	10	7	9
Thistle, Canada	9	8	9	9	10	8

[a] Spot treatment only.
[b] Perennial weeds may require more than one application.
[c] Spike is also an effective herbicide for multiflora rose control (weed susceptibility = 10).

Rating Scale:
10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, 6 = 55 to 65%, 5 = 45 to 55%, and 0 = less than 45% control or not labeled.

Table 6. Broadleaf Weed Control in Grass Pastures

Herbicide	Rate/acre	Remarks: See Table 7 for grazing restrictions.
2,4-D, 3.8 lb a.e. (amine or low-volatile ester)	2 to 4 pt	Broadleaf weeds should be actively growing. Higher rates may be needed for less susceptible weeds and some perennials. Spray bull or musk thistles in the rosette stage (spring or fall) while they are actively growing. Spray perennials such as Canada thistle in the bud stage or the fall regrowth stage. Spray susceptible woody species in spring when leaves are fully expanded. Do not apply to newly seeded areas or to grass when it is in boot to milk stage. Be cautious of spray drift.
Ally 60 DF	1/10 to 3/10 oz	Apply in the spring or early summer before annual broadleaf weeds are 4 inches tall. As a spot application for control of multiflora rose, blackberry, or Canada thistle, apply Ally at 1 ounce per 100 gallons of water and spray foliage to runoff. Include a surfactant of at least 80% active ingredient at 1 pint to 1 quart per 100 gallons spray solution (1/8 to 1/4% v/v). Bluegrass, bromegrass, orchardgrass, timothy, and native grasses such as bluestem and grama have demonstrated good tolerance. Bluegrass, bromegrass, orchardgrass, and timothy should be established for at least 6 months and fescue for 24 months at the time of application or injury may result. Application to fescue may result in stunting and seedhead suppression. Do not apply to ryegrass or pastures containing desirable alfalfa or clovers. Ally is persistent in soil, and crop rotation guidelines on the label must be followed.
Banvel, 4 lb a.e.	Annuals: 1 to 1½ pt Biennials: ½ to 3 pt Perennials: 1 to 12 pt	Use lower rates for susceptible annuals when they are small and actively growing and for susceptible biennials in the early rosette stage. Use higher rates for larger weeds, for less susceptible weeds, for established perennials in dense stands, and for certain woody brush species. Be cautious of spray drift.

Table 6. Broadleaf Weed Control in Grass Pastures (cont.)

Herbicide	Rate/acre	Remarks: See Table 7 for grazing restrictions.
Crossbow	Annuals: 1 to 2 qt Biennials and herbaceous perennials: 2 to 4 qt Woody perennials: 6 qt	Apply to foliage during warm weather when brush and broadleaf weeds are actively growing. When applying as a spot spray, thoroughly wet all foliage. See herbicide label for more specific rate recommendations. Be cautious of spray drift. Best control of multiflora rose occurs when application is during early- to mid-flowering stage.
Roundup	1 to 2% solution (spot treatment)	Controls a variety of herbaceous and woody brush species such as multiflora rose, brambles, poison ivy, and quackgrass. Spray foliage of target vegetation completely and uniformly, but not to point of runoff. Avoid contact with desirable nontarget vegetation. Consult label for recommended timing of application for maximum effectiveness on target species. No more than 1/10 of any acre should be treated at one time. Further applications may be made in the same area at 30-day intervals. Use only where livestock movement can be controlled to prevent grazing for 14 days. Treated areas can be reseeded after 14 days.
Spike 20P	10 to 20 lb	For control of brush and woody plants in rangeland and grass pastures. Requires sufficient rainfall to move herbicide into root zone. May kill or injure desirable legumes and grasses where contact is made. Injury is minimized by applying when grasses are dormant. Do not apply on or near field crops or other desirable vegetation. Do not apply where soil movement is likely. Refer to product label for additional restrictions.
Stinger, 3 lb a.e.	2/3 to 1 1/3 pt	Apply when weeds are young and actively growing. Grasses are tolerant, but new grass seedlings may be injured. For Canada thistle, apply to thistle at least 4 inches tall but before thistle reaches bud stage. Do not spray pastures containing desirable forbs, such as alfalfa or clover, unless injury can be tolerated. Do not use hay or straw from treated areas for composting or mulching on susceptible broadleaf crops. Refer to product label for additional precautions.

Table 7. Restrictions on Herbicides Used in Permanent Grass Pastures

Herbicide Name		Days after treatment (DAT) before use				
		Grazing		Grass hay		Slaughter withdrawal
Trade	Common	Beef	Dairy	Beef	Dairy	
Ally	metsulfuron	0	0	0	0	0
Banvel	dicamba	0	7 to 60[a]	0	37 to 90[a]	30
Crossbow	triclopyr + 2,4-D	0	14	7	365	3
Many	2,4-D	0	7 to 14[b]	30	30	3 to 7[b]
Stinger[c]	clopyralid	0	0	0	0	0
Roundup	glyphosate					
Spot-treat		14	14	14	14	...[d]
Renovation		56	56	56	56	...[d]
Spike 20P	tebuthiuron	(spot treatment)				
< 20 lb/A		0	0	365	365	...[d]
> 20 lb/A		Do not use for livestock for 1 year				
Weedmaster	dicamba + 2,4-D	0	7	37	37	30

[a] Varies with rate used per acre — see label.
[b] Labels vary (withdrawal unnecessary if > 14 DAT).
[c] Do not transfer livestock onto a broadleaf crop area within 7 days of grazing treated area.
[d] No information available.

Table 8. Effectiveness of Herbicides on Weeds in Legume and Legume-Grass Forages

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rate and weed size or growth stage. Performance may vary due to weather and soil conditions or other variables.

Weed	Balan	Buctril	Butyrac	Eptam	Gramox-one	Kerb	Poast Plus	Round-up[a,b]	Sencor/ Lexone[a]	Sinbar	Velpar
Winter annual											
Brome, downy	9	0	0	9	9	9	9	9	9	9	8
Chickweed, common	8	6	6	7	9	8	0	10	9	9	9
Henbit	5	8	6	9	9	8	0	8	9	9	8
Mustard, wild	0	8	10	6	9	5	0	9	9	9	9
Pennycress, field	0	9	8	6	9	5	0	10	9	9	9
Shepherdspurse	0	9	9	7	9	5	0	9	9	9	9
Yellow rocket	0	7	8	0	8	0	0	9	9	8	9
Summer annual											
Barnyardgrass	9	0	0	9	8	8	10	10	6	6	7
Crabgrass spp.	9	0	0	9	6	8	10	9	5	7	7
Foxtail spp.	9	0	0	9	9	8	10	10	6	7	7
Lambsquarters, common	9	10	8	9	9	6	0	9	9	9	9
Nightshade spp.[c]	0	9	8	8	9	6	0	9	5	6	6
Panicum, fall	9	0	0	9	9	6	10	10	6	6	6
Pigweed spp.	9	8	8	9	9	6	0	10	9	8	9
Ragweed, common	0	9	9	5	9	5	0	9	8	8	8
Smartweed, Pennsylvania	0	9	6	5	9	5	0	9	9	8	8
Perennial											
Canada thistle	0	0	0	0	0	0	0	9	0	0	0
Dandelion	0	0	7	0	0	0	0	8	8	6	7
Dock, curly	0	0	5	0	0	0	0	9	6	6	6
Nutsedge, yellow	0	0	0	8	0	0	0	7	0	0	0
Orchardgrass	5	0	0	6	5	7	6	8	5	5	6
Quackgrass	5	0	0	8	5	8	7	9	5	5	5

[a] Lexone, Sencor, and Roundup are labeled for use in mixed legume-grass forages. No other herbicides are cleared for this use.
[b] Spot treatment only.
[c] Control of different species may vary.

Rating Scale:
10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, 6 = 55 to 65%, 5 = 45 to 55%, and 0 = less than 45% control or not labeled.

Table 9. Weed Control in Legume Forages

Herbicide	Legume	Time of application	Broadcast rate/acre	Remarks: See Table 10 for haying restrictions.
Seedling year				
Balan 1.5EC	Alfalfa, birdsfoot trefoil, red clover, ladino clover, alsike clover	Preplant incorporated	3 to 4 qt	Apply shortly before seeding. Do not use with any companion crop of small grains.
Eptam 7E,10G	Alfalfa, birdsfoot trefoil, lespedeza, clovers	Preplant incorporated	3½ to 4½ pt (7E) 30 lb (10G)	Apply shortly before seeding. Do not use with any companion crop of small grains.
Gramoxone Extra	Alfalfa only	Between cuttings	12.8 fluid oz	Apply within 5 days after cutting and before alfalfa regrowth is 2 inches. Add surfactant according to label instructions. Do not apply more than twice during seedling year. *Gramoxone Extra is a restricted-use pesticide.*
Buctril 2E	Alfalfa only	Postemergence	16 to 24 fl oz	Apply in the fall or spring to seedling alfalfa with at least 4 trifoliate leaves. Apply to weeds at or before the 4-leaf stage or 2 inches in height (whichever is first). May be tank-mixed with 2,4-DB for improved control of pigweed; however, crop burn may occur from this mixture, especially under warm, humid conditions. Eptam, previously used, may enhance Buctril burn to alfalfa. Do not apply when temperatures are likely to exceed 70°F during or for 3 days following application or when the crop is stressed. Do not add a surfactant or crop oil.
Butyrac 200 or Butoxone 200	Alfalfa, birdsfoot trefoil, ladino clover, red clover, alsike clover, white clover	Postemergence	1 to 3 qt (amine)	Use when weeds are less than 3 inches tall or less than 3 inches across if rosettes. Use higher rates for seedling smartweed or curly dock. May be tank-mixed with Poast Plus. *Do not use on sweet clover.*
Kerb 50W	Alfalfa, birdsfoot trefoil, crown vetch, clovers	Postemergence	1 to 3 lb	In fall-seeded legumes, apply after legumes have reached trifoliate stage. In spring-seeded legumes, apply next fall.
Poast Plus	Alfalfa only	Postemergence	1⅛ to 2¼ pt	Best grass control is achieved when applications are made prior to mowing. If tank-mixed with 2,4-DB, follow 2,4-DB harvest and grazing restrictions. Do not apply more than a total of 9.75 pints of Poast Plus per acre in one season.

Table 9. Weed Control in Legume Forages (cont.)

Herbicide	Legume	Time of application	Broadcast rate/acre	Remarks: See Table 10 for haying restrictions.
Established stands				
Butyrac 200 or Butoxone 200	Alfalfa only	Growing	1 to 3 qt (amine)	Spray when weeds are less than 3 inches tall or less than 3 inches wide if rosettes. Fall treatment of fall-emerged weeds may be better than spring treatment. May be tank-mixed with Poast Plus.
Kerb 50W	Alfalfa, birdsfoot trefoil, crown vetch, clovers	Growing or dormant	1 to 3 lb	Apply in the fall after last cutting, when weather and soil temperatures are cool. *Kerb 50W is a restricted-use pesticide.*
Sencor or Lexone	Alfalfa and alfalfa-grass mixtures	Dormant	¾ to 2 pt (4L) ½ to 1⅓ lb (75 DF)	Apply once in the fall or spring before new growth starts. Rate is based upon soil type and organic-matter content. Higher rates may injure grass component. Do not use on sandy soils or soils with pH greater than 7.5.
Sinbar 80W	Alfalfa only	Dormant	½ to 1½ lb	Apply once in the fall or spring before new growth starts. Use lower rates for coarser soils. Do not use on sandy soils with less than 1 percent organic matter. Do not plant any crop for 2 years.
Velpar L	Alfalfa only	Dormant	1 to 3 qt	Apply in the fall or spring before new growth exceeds 2 inches in height. Can also be applied to stubble after hay crop removal but before regrowth exceeds 2 inches. Do not plant any crop except corn within 2 years of treatment. Corn may be planted 12 months after treatment provided deep tillage is used.
Poast Plus 1E	Alfalfa only	Postemergence	1⅛ to 2¼ pt	Best grass control is achieved when applications are made prior to mowing. If tank-mixed with 2,4-DB, follow 2,4-DB grazing and harvest restrictions. Do not apply more than a total of 9.75 pints of Poast Plus per acre in one season.
Gramoxone Extra	Alfalfa only	Dormant	1½ to 2 pt	For dormant season, apply after last fall cutting or before spring growth is 1 inch tall. Weeds should be succulent and growing at the time of application. Do not apply if fall regrowth is more than 6 inches. *Gramoxone Extra is a restricted-use pesticide.*
		Between cuttings	12.8 fl oz	Between cutting treatments should be applied immediately after hay removal within 5 days after cutting and with less than 2 inches of growth. Weeds germinating after treatment will not be controlled. *Gramoxone Extra is a restricted-use pesticide.*
Roundup	Alfalfa, clover, and alfalfa or clover-grass mixtures	Growing	1 to 2% solution (spot treatment)	No more than ⅒ of any acre should be treated at one time. Further applications may be made in the same area at 30-day intervals. Avoid contact with desirable, nontarget vegetation because damage may occur. Refer to label for recommended timing of application for maximum effectiveness on target species.

Table 10. Herbicides Used in Forage Legumes and Restrictions

Herbicide name		Applied on/at		Days before	
Trade	Common	Forage[a]	When[a]	Graze	Hay
Seedling legumes					
Balan	benefin	AL, CL, BT	PPI	. . .[b]	. . .[b]
Eptam	EPTC	AL, CL, BT	PPI	. . .[b]	. . .[b]
Butyrac, Butoxone	2,4-DB	AL, CL, BT	Post	60	60
Buctril	bromoxynil	AL	Post-fall	60	60
		AL	Post-spring	30	30
Gramoxone Extra	paraquat	AL	After cut[c]	30	30
Poast Plus	sethoxydim	AL	Post	7	20
Established legumes					
Many	2,4-DB	AL	Post	30	30
Gramoxone Extra	paraquat	AL	After cut[c]	30	30
Poast Plus	sethoxydim	AL	Post	7	20
Roundup	glyphosate	AL, CL, BT	Spot-treat	14	14
Roundup	glyphosate	AL, CL, BT	Renovate	56	56
Gramoxone Extra	paraquat	AL	Dormant	60	60
Kerb	pronamide	AL, CL, BT	Dormant	120	120
Lexone	metribuzin	AL	Dormant	28	28
Sencor	metribuxin	AL	Dormant	28	28
Sinbar	terbacil	AL	Dowmant	. . .[b]	0
Velpar	hexazinone	AL	Dormant	30	30

[a] AL = alfalfa, CL = clover (red, alsike, or ladino), BT = birdsfoot trefoil, PPI = preplant-incorporated.
[b] No grazing information on label.
[c] Between cuttings (less than 5 days after cut with less than 2 inches regrowth).

5 Controlling Johnsongrass, Shattercane, and Sorghum-Almum in Illinois

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Johnsongrass (*Sorghum halepense*) is a perennial that reproduces by seeds and rhizomes. Johnsongrass is a problem weed in Illinois, particularly in the southern half of the state where the rhizomes can overwinter. In the colder climate of northern Illinois, johnsongrass spreads primarily by seed.

Johnsongrass rhizomes are freely branching, fleshy, scaly, and white with purple spots. They may grow to several feet in length and may reach a diameter of 0.75 inch. The plant may be from 3 to 10 feet tall, depending on the biotype and the environment. Johnsongrass has a large, open, panicle-type seedhead that is purplish, hairy, and diversely branched. The seeds are oval, with a glossy mahogany cast. They are 0.13 to 0.15 inches long and are enclosed in straw-colored glumes.

Shattercane (*Sorghum bicolor*), often called wild cane, is an annual that reproduces only by seed. Although shattercane does not produce rhizomes, it can be almost as difficult to control as the perennial sorghums because it is capable of producing several flushes of seedlings in one season.

Shattercane closely resembles cultivated sorghum or sudangrass. Because the plant readily tillers, several stems may grow from a single crown. Shattercane has a panicle-type seedhead that varies from compact to loose to open. The seeds are oval and are usually enclosed in shiny black to dark mahogany glumes. The seedheads may droop to one side at maturity. The seeds usually shatter before the crop is harvested.

Sorghum-almum (*Sorghum almum*) is a cross between johnsongrass and a cultivated sorghum. Because this cross produces a plant with uneven sets of chromosomes, sorghum-almums with a range of characteristics between johnsongrass and shattercane can be found. Some plants have norhizomes; others have short rhizome spurs that grow upward towards the soil surface; and still others have true johnsongrass-like rhizomes. The plant reproduces primarily by seed. However, some of the rhizomes may survive a mild winter if they are deep enough in the soil. In this case, new plants may be produced from those rhizomes the following spring.

Sorghum-almum generally resembles shattercane in its vegetative characteristics. Various seedhead types exist because of the plant's genetic variability. Often the seeds are smaller than shattercane but less elongated than johnsongrass; however, the seeds too are variable in appearance.

Prevention

Prevention of the establishment of the weedy sorghum species is an essential part of the overall control program. Johnsongrass, sorghum-almum, and shattercane can be spread by birds, livestock, or water, or by contaminated feed, machinery, or crop seed. The seeds remain viable in the soil for several years. Therefore, many areas are continually plagued with new seedlings even though established plants are controlled.

New johnsongrass and sorghum-almum plants also develop from overwintering rhizome buds located at each rhizome node. When rhizome pieces are moved and deposited into clean soil, the area may become infested.

Whether you are attempting to prevent initial infestation or minimize reinfestation after a successful control program, it is important that you scout your fields and nearby noncrop areas regularly and destroy any of these plants before they establish and spread. Take the following precautions to prevent the spread of weedy sorghum seeds and rhizomes:

1. Plant only clean crop seed that is free of johnsongrass, shattercane, and sorghum-almum seed.

2. When planting sorghum, plant only pure, cultivated sorghum seed that has been produced un-

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

der proper isolation to reduce cross-pollination. Cut forage-type sorghums of sorghum-sudan hybrids before the seed matures.

3. Do not bring straw and hay from an infested area into a noninfested area.

4. Do not move livestock from an infested pasture into a noninfested field.

5. Clean all machinery, particularly combines where seeds might lodge, before moving it from an infested to a noninfested field.

6. Avoid dragging rhizome pieces on farm implements from an infested area to a noninfested area.

7. Immediately rogue or spot-treat all plants when they appear.

8. Do not let plants develop mature seed. As soon as seedheads emerge, cut them from the plant. Then carry the seedheads out of the field and burn them or bury them in a common "grave."

Control Programs

Effective long-term control of shattercane, johnsongrass, and sorghum-almum involves integrating cultural, mechanical, preventative, and chemical methods that prevent seed and rhizome production and reduce the number of viable seeds in the soil. Several years of good management are required to totally rid an area of these species.

Corn and Soybean Programs

The weedy sorghum species are tolerant of many corn herbicides. The thiocarbamates are selective, soil-applied corn products for sorghum control (Table 1). They give fair control, and they must be incorporated. When used year after year, accelerated breakdown of the thiocarbamates frequently develops. Therefore, they should not be used annually for the control of weedy sorghums.

Accent and Beacon are selective postemergence herbicides that control weedy sorghums. They can be used in a single application for shattercane, sorghum-almum, or seedling johnsongrass; in some instances, two applications may improve the control of rhizome johnsongrass. Cultivation will also improve weed control but should be delayed until at least 7 days after the herbicide is applied. Pursuit can also be used for the control of sorghums in Pursuit-resistant or -tolerant corn hybrids.

These postemergence products should greatly improve our ability to manage weedy sorghums in corn. However, the potential exists for the development of resistance if these herbicides are used on the same area for several consecutive years. Therefore, it is recommended that they be rotated or tank-mixed with other types of herbicides and, if possible, supplemented with cultivation. Rotating the field to another crop can also allow the use of products that will not add to the potential for the development of resistance.

Rotation to soybeans allows the use of effective herbicides with less likelihood for development of resistance (Table 2). The soil-applied soybean herbicides are more effective than the corn herbicides but usually do not provide total control. Several selective postemergence herbicides are available that are very effective against grass weeds. A disadvantage with using these products is timing. Since sorghum species emerge later than many of the common annual grasses, it may not be possible to use one application to control all grass species for the entire season.

The basic control strategies for soybeans might include applying a dinitroaniline (DNA) herbicide followed by a postemergence herbicide (broadcast or band plus cultivation) or applying a split application of a postemergence herbicide.

Soil-applied Herbicides in Corn and Soybeans

Proper soil preparation is critical for soil-applied herbicides to effectively control seedlings and rhizomes. Before incorporating a preplant herbicide, prepare the ground with a chisel plow to bring rhizomes to the surface and then disk to cut them into small pieces. If the primary tillage operation is conducted in the fall, the rhizome pieces will be exposed to freezing and thawing, which reduces their viability. After large soil clods and excess residues are minimized, the field is ready for a preplant-incorporated herbicide.

If the weedy sorghum has just been introduced into the area and you are attempting to control seedlings before the infestation is well established, it is better to minimize the amount of mixing of the seeds in the soil. This will prevent their being buried where they can be dormant for several years and later brought to the surface.

Uniform distribution of the herbicide applied at the rate labeled for johnsongrass, sorghum-almum, or shattercane is essential if a soil-applied treatment is going to be effective. Improper herbicide incorporation or low herbicide use rates often result in poor control. Large-diameter cutting disks do a poor job of incorporating the herbicide. Disk twice, with the second disking at an angle to the first. A tandem disk puts the herbicide at about half the operational depth; therefore, set and operate the disk to cut 4 to 6 inches for the first disking and, at most, 4 inches for the second disking. Do not incorporate the herbicide deeper than 3 inches. Most of the soil-applied herbicides used for the control of weedy sorghum species will benefit from immediate incorporation to minimize the amount of herbicide lost.

Most preplant-incorporated herbicides must be applied at a considerably higher rate to control the sorghum species than to control most annual grasses. Even at the higher rate, these treatments only suppress plants emerging from rhizomes and they often allow some seedlings to escape. Seedling control can be good if conditions are ideal.

Cultivation is usually required regardless of the preplant herbicide used. Time the cultivations carefully. To control johnsongrass and sorghum-almum, repeat the cultivations at intervals of two to three weeks in order to prevent new rhizome growth. Shattercane plants should be destroyed before they develop seedheads. Set the cultivator sweeps for shallow cultivation—2 inches or less—and avoid cultivating below the depth at which the herbicide was incorporated. Deep cultivation brings untreated soil containing viable seeds to the surface where the seeds can germinate.

Postemergence Grass Herbicides in Corn

Accent, Beacon, and Pursuit provide excellent seedling control of weedy sorghums. Rhizome johnsongrass control might be improved with a split application. Be sure to read all label precautions pertaining to corn and weed size, as well as the use of these products with insecticides and other herbicides.

Postemergence Grass Herbicides in Soybeans

These herbicides provide excellent seedling control and rhizome suppression or control. Retreatment with a reduced rate is often necessary for rhizome control, especially in no-till fields where the recommended soil-applied herbicide was not used. Assure, Fusion, and Fusilade have generally provided better rhizome control from a single application than the other products. Select the appropriate rate according to weed size. Follow the label recommendations on the use of a surfactant or crop oil concentrate.

Foliar Spot Treatment

Scattered johnsongrass, sorghum-almum, and shattercane plants not controlled by soil-applied herbicides or cultivation should be controlled by other methods. Roguing or spot-treating with glyphosate (Roundup) is an integral part of the control program. Plants that escape will produce seeds (shattercane) or both seeds and rhizomes (the perennial sorghums) that will reinfest the field.

Roundup is the only herbicide now labeled for spot application in corn and soybeans. Applying Roundup as a spot treatment or with selective application equipment is more effective in soybeans than in corn because the size of the soybean plants allows for easier selective application of the herbicide. A spot application is made with a 1 percent solution (1-1/2 ounces of Roundup per gallon of water). An over-the-top, directed application is a 33 percent solution (1 gallon of Roundup per 2 gallons of water) applied with a recirculating sprayer or ropewick applicator. Shattercane should be treated before it produces seedheads, and the perennial sorghums should be treated in the boot stage or when plants are at least 18 inches tall. Apply carefully because crop plants sprayed with Roundup will be severely injured. Roundup can also kill or severely injure crops and other desirable plants if it is applied to or drifts onto them.

Winter Grain and Fallow Programs

Winter grain production followed by summer fallow can effectively reduce stands of weedy sorghums as well as prevent the production of seeds and rhizomes and reduce their number in the soil. For this program to be successful, all sorghum plants that emerge during fallow must be destroyed before they produce seeds or rhizomes.

After the small grain is harvested, plow and disk as thoroughly as your soil type and slope will allow. Repeat the diskings at intervals of 2 to 3 weeks to destroy seedlings and to keep emerging plants from developing rhizomes. Tillage can destroy weed seedlings by covering them with soil or by allowing them to desiccate. Cutting rhizomes into small sections can reduce their viability by exposing them to drying conditions.

Where tillage is not an option following a grain crop, apply Fusilade, Roundup, or Touchdown for rhizome and seedling control (Table 3). Often another application is required later in the season to control new seedlings or regrowth from rhizomes. To be most effective, it is important that regrowth or newly emerging seedlings be controlled; otherwise, the field will become reinfested.

Use a good seedling control program when returning to row crops after the production of winter grain or forage, or reinfestations may occur.

Forage, Grazing, and Mowing Programs

A competitive forage crop, such as alfalfa, can somewhat reduce the competitiveness of shattercane, johnsongrass, and sorghum-almum seedlings. Regular harvesting, grazing, or repeated mowings of forage crops reduces seed production and rhizome vigor. Although pasturing and mowing will not eliminate the weed, the weakened plants will be more susceptible to other control measures.

Noncropland Programs

Johnsongrass, sorghum-almum, and shattercane plants in fencerows and other noncrop areas are potential sources for reinfestations of crop areas. Eliminate all weedy sorghum plants in noncrop areas to prevent further seed or rhizome production that will allow the weed to spread. Roundup or Touchdown can be used to treat large infestations of the weeds. Several other herbicides are labeled as well (Table 4). Dense johnsongrass infestations will probably require retreatment.

Even after successfully managing your weedy sorghum for years, new infestations can develop from dormant seed or new seed. Scout your fields and noncrop areas regularly, and immediately rogue or spot-treat any weeds that develop.

Some of the herbicides labeled for use in noncropland areas have long soil life and may be mobile in the soil. Do not use these herbicides where you will grow crops in the near future or where conditions are conducive for their movement into groundwater. Most labels specify that the treated area should not be grazed or the treated plants fed to livestock.

Table 1. Control of Johnsongrass, Shattercane, and Sorghum-almum with Corn Herbicides

Herbicide	Rate per acre	Remarks
Preplant-incorporated (PPI) application: seedling and rhizome suppression		
Eradicane Extra 6E	8 pt	
Sutan + 6.7E	7-1/3 pt	
Postemergence (POE) broadcast application		
Accent	2/3 oz	Shattercane, sorghum-almum, or seedling johnsongrass 4 to 12 inches tall. A second application of 2/3 ounce per acre can be made 14 to 28 days later to control a new weed flush.
	2/3 oz + 2/3 oz	Rhizome johnsongrass: Make the first application when plants are 8 to 18 inches tall and the second when regrowth is 8 to 10 inches tall.
Beacon	1/2 packet (0.76 oz) maximum in a single application	Shattercane, sorghum-almum, or seedling johnsongrass 4 to 12 inches tall.
	split application of either 1/4 packet + 1/4 packet or 3/8 packet + 1/8 packet	Rhizome johnsongrass: Make the first application when plants are 8 to 16 inches tall; second application when regrowth is 8 to 16 inches tall.
Pursuit	4 fl oz	Use only on Pursuit-resistant or -tolerant corn hybrids. Apply to 1- to 8-inch-tall shattercane or johnsongrass seedlings.

Table 1. Control of Johnsongrass, Shattercane, and Sorghum-almum with Corn Herbicides (cont.)

Herbicide	Rate per acre	Remarks
Postemergence (POE) soil application with incorporation		
Prowl 4E	1-1/2 to 3 pt	Corn 4 inches to lay-by. Cultivate before application to cover base of corn plant. Lightly incorporate.
Treflan 4E	1-1/2 to 2 pt	Corn two-leaf stage or taller. Cultivate before application to cover base of corn plant. Lightly incorporate.
Postemergence (POE) spot treatment		
Roundup 4E	1% solution (1-1/2 oz per gal of water)	

Table 2. Control of Johnsongrass, Shattercane, and Sorghum-almum with Soybean Herbicides

Herbicide	Rate per acre	Remarks	
Preplant-incorporated (PPI) application: seedling control			
Passport	2-1/2 pt		
Prowl 4E	2 to 3 pt		
Pursuit Plus	2-1/2 pt		
Sonalan 3E	2 to 3 pt		
Treflan 4E	2 to 2-1/2 pt		
Preplant-incorporated (PPI) application: seedling control and rhizome suppression			
Prowl 4E	2 to 4 pt		
Treflan 4E	2 to 4 pt		
Postemergence (POE) application: seedling control			
		Shattercane height	Johnsongrass or sorghum-almum height
Assure II 0.88E	5 fl oz	6 to 12 inches	2 to 8 inches
Fusilade 2000 1E	12 fl oz	6 to 12 inches	2 to 8 inches
Fusion 2.67EC	6 to 8 fl oz	6 to 12 inches	2 to 8 inches
Option II 0.79E	6.4 fl oz	6 to 12 inches	4 to 10 inches
Poast Plus 1E	24 fl oz	6 to 18 inches	less than 8 inches
Pursuit 2S	4 fl oz	1 to 8 inches	1 to 8 inches
Select	6 to 8 fl oz	4 to 10 inches	4 to 10 inches

Table 2. Control of Johnsongrass, Shattercane, and Sorghum-almum with Soybean Herbicides (cont.)

Herbicide	Rate per acre	Remarks
Postemergence (POE) application: seedling and rhizome control		
		Johnsongrass or sorghum-almum height
Assure II 0.88E		
1st application	10 fl oz	10 to 24 inches
2nd application	7 fl oz	6 to 10 inches
Fusilade 2000 1E		
1st application	24 fl oz	8 to 18 inches
2nd application	16 fl oz	6 to 12 inches
Option II 0.79E:		
1st application	16 fl oz	10 to 20 inches
2nd application	8 fl oz	10 to 20 inches
Poast Plus 1E		
1st application	24 fl oz	15 to 25 inches
2nd application	24 fl oz	6 to 12 inches
Select		
1st application	8 fl oz	12 to 24 inches
2nd application	6 fl oz	6 to 10 inches
Postemergence (POE) spot treatment		
Roundup 4E	1% solution (1-1/2 oz per gal of water)	
Postemergence (POE) directed treatment (ropewick applicator or recirculating sprayer)		
Roundup 4E	33% solution (1 gal per 2 gal of water or 5 oz per 1 gal of water)	

Table 3. Control of Johnsongrass, Shattercane, and Sorghum-almum on Fallow Ground or Noncropland

Herbicide	Rate per acre	Remarks
Postemergence (POE) broadcast applications		
Fusilade 2000	32 to 48 oz	Shattercane, sorghum-almum, or seedling johnsongrass 2 to 8 inches tall and before tillering or heading. Rhizome johnsongrass 8 to 18 inches tall and before boot stage.
Roundup 4E	12 oz	Shattercane up to 12 inches tall.
Roundup 4E	1 to 3 qt	Plants 18 inches tall.
Touchdown 6S	2 to 2-2/3 pt	

Table 3. Control of Johnsongrass, Shattercane, and Sorghum-almum on Fallow Ground or Noncropland (cont.)

Herbicide	Rate per acre	Remarks
Postemergence (POE) spot applications		
Roundup 4E	1% solution (1-1/2 oz per gal of water)	
Touchdown 6S	1.5 to 2% solution (2 to 2-2/3 fl oz per gal of water)	

Table 4. Control of Johnsongrass, Shattercane, and Sorghum-almum on Noncropland Only

Herbicides with long residual activity should not be used where you have plans for crops in the near future or where conditions are conducive for the herbicide to move into surface waters or the groundwater.

Herbicide	Rate	Remarks
Soil-applied spot application		
Arsenal 5G	20 lb/A	Distribute evenly.
Pramitol 5PS	2 lb/100 sq ft	Contains sodium chlorate for additional activity.
Hyvar X-L (3 lb/gal)	6 to 12 gal/A	Soil or stubble.
Postemergence (POE) spot application		
Arsenal	2 to 3 pt/A	Postemergence.
Asulox	1 to 2 gal/A	Plants 18 inches tall; no soil activity.
Horizon	19 to 45 oz/100 gal water	Rate varies with size and life cycle of weed. Retreatment may be required. May be safe to use in areas of most native grasses: see label.
Horizon 2000	9 fl oz/100 gal water	Do not use on desirable stands of native grasses.
Pramitol 25E	4 to 5.5 pt/1,000 sq ft	Foliar or stubble. Distribute thoroughly.
Oust	2 to 5 oz/A	Early postemergence. Temporary suppression; re-treat regrowth.
Oust	6 to 12 oz/A	Early postemergence.

6 Plant Disease Management for Field Crops

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The best way to ensure success of a disease management program is to adapt it to the diseases expected and to use integrated disease control measures. Among these measures are the use of resistant varieties, crop rotations, fungicides, nematicides, and suggested agronomic practices. The success of any one or all of these measures may depend on how carefully you scout your crops. Because periodic crop scouting increases the likelihood that disease controls will be applied properly, it can help prevent loss through disease and unnecessary use of pesticides.

Specific information for the control of the important diseases of corn, soybeans, wheat, and alfalfa can be found in Table 1 and in the following current issues of *Report on Plant Diseases:* No. 123, "Winter Wheat Disease Management Program"; No. 212, "Illinois Corn Disease Management Program"; No. 308, "Alfalfa Disease Management Program"; No. 507, "Illinois Soybean Disease Management Program"; and No. 1001, "Seed Treatments for Field Crops."

These and other issues of *Report on Plant Diseases* are available from Extension Plant Pathology, University of Illinois, N-533 Turner Hall, 1102 South Goodwin Avenue, Urbana, IL 61801.

Federal and State Laws Restricting Pesticide Application

The U.S. Environmental Protection Agency (USEPA) classifies pesticides for "general" or "restricted" use. Applying a restricted-use pesticide, whether "commercial" or "private," requires certification.

Commercial applicators include not only persons applying restricted-use pesticides for hire but also government personnel, chemical company representatives, and others involved in demonstrational, regulatory, and public health pest control. Certification as a commercial applicator requires passing a written examination administered either by the Illinois Department of Agriculture or the Illinois Department of Public Health.

Private applicators who use restricted-use pesticides "for the purpose of producing any agricultural commodity on property owned or rented by [the applicator] or as exchange labor (no compensation) on the property of another must also be certified, either by attending an educational training program or by passing an examination."

Educational training programs for farmers (private applicators) and commercial pesticide applicators are conducted by the Illinois Cooperative Extension Service to prepare persons for certification. The actual certification and the issuing of permits or licenses are handled by the Illinois State Department of Agriculture.

Always Read the Label Before Using a Pesticide

The pesticide names used in this publication include both the common, or coined, chemical names and representative trade names. The common name is the active ingredient (for example, benomyl) and is not capitalized. The trade name is a specific company's product name and is capitalized (for example, Benlate). In many cases, multiple company product names exist for products containing the same active ingredient. In such cases, the specific company product names have been replaced by the term *many*. In addition, there are many formulations and product combinations available. Consult your local Extension office or agrichemical dealer for additional information. Before making any pesticide application decision, refer to the most recent label for rates, days to harvest, and other information.

Fungicide Application

At present, aircraft are the best vehicles for applying foliar fungicides to agronomic crops. Some aircraft may not be equipped or calibrated to do this job. It is therefore important to select an aerial applicator who is familiar with disease control and whose aircraft has

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The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

Table 1. Condensed Disease-Control Recommendations for Field Crops

Crop/ Disease	Fungicide or nematicide: Common name	Trade name	Comments
Alfalfa			
Seed rots and seedling blights	captan thiram metalaxyl oxadixyl	many many Apron Anchor	Seed treatment is not usually necessary with high-quality seed. Metalaxyl and oxadixyl control only Pythium seedling blight.
Bacterial wilt, Phytophthora root rot			Resistance should be strongly considered when choosing a variety.
Leafspots, spring blackstem, and anthracnose	copper hydroxide	Kocide	Cut forage in a timely manner to maximize yields and minimize leaf loss. Grow adapted resistant varieties.
Crown and root rots			Maintain proper fertility and soil pH. Avoid cutting or grazing during the last 5 to 6 weeks of the growing season. Control insect pests.
Verticillium wilt			Seed treatment with thiram is suggested to prevent seed transmission. This disease will only be a problem in stands that are more than 3 years old. Resistant varieties should also be considered.
Sclerotinia white mold			Spring planting, deep and clean plowing, using 3- to 4-year rotations with nonlegume crops, and avoiding excessively lush growth may reduce disease severity. Chemical controls are not available. The variety Cimarron is reported to be moderately resistant.
Barley			
Seed rots, seedling blights, loose smut	carboxin thiram captan PCNB metalaxyl	Vitavax many many Terra-Coat Apron	Seed treatment is strongly suggested. Carboxin is required for loose smut control. Metalaxyl only controls Pythium seedling blight.
Barley yellow dwarf virus			Plant winter barley after the fly-free date and spring barley as early as possible.
Clover			
Anthracnose diseases			Grow adapted resistant varieties.
Crown and root rots			Same as for alfalfa.
Seed rots and seedling blights			Same as for alfalfa.

Table 1. Condensed Disease-Control Recommendations for Field Crops (cont.)

Crop/ Disease	Fungicide or nematicide		Comments
	Common name	Trade name	
Corn			
Seed rots and seedling blights	captan carboxin thiram metalaxyl	many Vitavax many Apron	Sow injury-free, plump seed in soils at 50°F or above. Prepare the seedbed properly and place herbicide, fertilizer, insecticide, and seed correctly. Note: fungicide plus insecticide seed treatments are commonly used.
Helminthosporium leaf diseases Northern leaf blight Southern leaf blight Northern leaf spot	chlorothalonil mancozeb	Bravo Dithane M-45 Manzate 200 Penncozeb	Plant resistant hybrids. Chlorothalonil is only registered for corn grown for seed and sweet corn. Begin applications when conditions favor disease development, and repeat at 4- to 7-day intervals or as required to maintain control. Do not apply within 14 days of harvest. Do not apply to sweet corn to be processed. Do not feed fodder or forage to livestock.
Common rust and southern rust	chlorothalonil	Bravo	Same as for Helminthosporium leaf blights.
Stewart's disease			Plant resistant hybrids or use insecticides to control flea beetles when necessary.
Goss's bacterial wilt and leaf blight			Plant resistant hybrids. Clean plowdown and 2-year crop rotations also give control. Use clean plowdown only where erosion will not be a problem.
Anthracnose, Physoderma brown spot, eyespot, yellow leaf blight			Plant resistant or tolerant hybrids. Practice crop rotation or clean tillage where soil-erosion considerations allow.
Crazy top and sorghum downy mildew			Plant resistant or tolerant hybrids. Improve drainage in affected area. Control wild cane to reduce sorghum downy mildew inoculum.
Virus diseases			Plant resistant hybrids. Control johnsongrass to reduce overwintering source of MDMV and MCDV.

Table 1. Condensed Disease-Control Recommendations for Field Crops (cont.)

Crop/ Disease	Fungicide or nematicide: Common name	Fungicide or nematicide: Trade name	Comments
Stalk rots *Diplodia* Charcoal *Gibberella* *Nigrospora* *Fusarium* Anthracnose			Plant hybrids with good stalk rot resistance and stalk strength. The use of a nitrogen stabilizer may be helpful where nitrogen loss is expected. Maintain adequate phosphorus and potassium fertility for the rate of nitrogen used. Control corn borers and corn rootworms. Scout fields at 30 to 40 percent moisture for lodging potential. Walk a zigzag pattern through the field pushing random plants about 5 inches from the vertical. If more than 10 to 15 percent lodge, schedule the field for early harvest.
Storage molds *Penicillium* spp. *Aspergillus* spp.	propionic acid, and other formulations of propionic acid		Grain treated with an acid grain preservative can be used only for animal feed. Store undamaged corn at 15 to 15.5 percent moisture from fall until spring, then dry to 13 percent for long-term storage. Grain damaged by field molds, insects, etc. should be dried to 13 to 13.5 percent moisture at harvest. Watch stored grain for heating, a musty odor, crusting, or other signs of storage mold activity. Control stored grain insects. Make sure combine is adjusted to avoid damage to grain. Remove fines and foreign material before storage.
Nematodes Root-lesion Needle Dagger Spiral Lance	carbofuran ethoprop terbufos	Furadan Mocap Counter	Use nematicidal rates of these materials only where soil tests indicate economic populations of nematodes. Use crop rotation where appropriate. For needle nematode control, avoid small grains in rotations and control grass weeds. More than 1 species of root lesion nematodes may be present in a field. Species identification should be made before selecting rotation crops.
Oats			
Seed rots and seedling blights	captan carboxin thiram PCNB	many Vitavax many Terra-Coat	Seed treatment is strongly suggested for control of smut diseases.

Table 1. Condensed Disease-Control Recommendations for Field Crops (cont.)

Crop/ Disease	Fungicide or nematicide: Common name	Trade name	Comments
Barley yellow dwarf			Grow resistant varieties. Plant susceptible varieties as early in the spring as possible.
Crown rust			Plant resistant varieties. Fungicides applied for *Septoria* and *Helminthosporium* will also aid in crown rust control.
Sorghum			
Seed rots, seedling blights, and smuts	captan thiram PCNB mancozeb	many many Terra-Coat Dithane M-45 Manzate 200 Penncozeb	Fungicide seed treatment is strongly suggested. Plant in soils at 60° to 65°F or above.
Other diseases			Plant resistant or tolerant hybrids. Diseases other than the smuts have not been important in Illinois.
Nematodes	aldicarb carbofuran	Temik Furadan	Apply only where soil analysis indicates an economic problem.
Soybeans			
Seed rots and seedling blights (primarily *Pythium, Phytophthora, Rhizoctonia*)	captan carboxin PCNB metalaxyl oxadixyl	many Vitavax Terra-Coat Apron Anchor	Plant high-quality seed germinating greater than 70 percent in a cold germination test. Seed treatment is recommended where (1) seed of poor quality due to fungal infection must be planted; (2) delays in emergence are anticipated; (3) seed is planted to produce seed; (4) reduced seeding rates are used; and (5) seed is planted into heavy crop (reduced or no-till). Plant in soils at 55°F or above. Metalaxyl and oxadixyl control Pythium. Metalaxyl will control Phytophthora. Oxadixyl will suppress Phythophthora.
Charcoal rot			Plant full-season varieties as early as possible. Avoid excessive seeding rates and maintain optimal fertility. Deep fall plowing may be beneficial where soil-erosion concerns allow.

Table 1. Condensed Disease-Control Recommendations for Field Crops (cont.)

Crop/ Disease	Fungicide or nematicide: Common name	Fungicide or nematicide: Trade name	Comments
Brown stem rot			Rotate, using 2 years of corn in fields where disease has been damaging. The varieties BSR 301, BSR 302, BSR 201, BSR 101, and Chamberlain have moderate resistance.
Sclerotinia white mold			Rotate with nonlegume crops. Plant moderately resistant varieties in fields where disease has been present before.
Phytophthora root rot	metalaxyl	Apron and Ridomil	Plant varieties with race-specific or field resistance (tolerance). Race-specific resistance will provide immunity to specific races. However, in some areas, races of the *Phytophthora* fungus are present that can attack this type of resistance. Varieties with field tolerance are resistant after two sets of trifoliate leaves develop. However, they are very susceptible to the seedling blight phase of the disease. Therefore, varieties with field tolerance should be protected in the seedling stage with metalaxyl fungicide applied as a seed treatment. Varieties with field tolerance can be protected for 6 to 8 weeks after planting by using metalaxyl as a band or furrow treatment at planting.
Soybean cyst nematode	aldicarb	Temik	Maintain proper soil fertility. Rotate with nonhost crops such as corn, small grains, red clover, alfalfa, and with SCN-resistant soybean varieties. An example of a rotation following SCN-damaged soybeans: corn followed by an SCN-resistant variety followed by corn. Monitor SCN populations by taking soil samples after third year. If populations are below the level for damage, use a high-yielding susceptible soybean variety to reduce the buildup of a different race. If populations are above the damage level, plant a nonhost crop and repeat soil sampling. Nematicides are suggested only where (1) crop rotations are not possible and (2) resistant varieties are not readily available. Aldicarb has given the most consistent control; applied in-furrow, it has given control equal to higher rates applied in bands. Both aldicarb and carbofuran can be applied in-furrow. See

Table 1. Condensed Disease-Control Recommendations for Field Crops (cont.)

Crop/ Disease	Fungicide or nematicide: Common name	Fungicide or nematicide: Trade name	Comments
			Report on Plant Diseases No. 501 for more information.
Root lesion nematode	aldicarb carbofuran	Temik Furadan	There are no soybean varieties resistant to root-lesion nematodes. Consequently, crop rotation and nematicides are the most practical approaches for controlling lesion nematodes. These control approaches are discussed in *Report on Plant Diseases* No. 1103, entitled "Lesion Nematodes."
Sudden death syndrome			No direct control methods have been identified. Controlling the soybean cyst nematode may be beneficial. Early maturing or early planted beans appear more susceptible.
Pod and stem blight, anthracnose, stem canker, Septoria brown spot, Cercospora leaf blight, and purple seed stain	benomyl chlorothalonil thiophanate-methyl thiabendazole	Benlate Bravo Topsin-M Mertect 340	Suggested for use where disease conditions warrant (see Table 3). Two applications of benomyl and thiophanate-methyl are suggested for maximum yield and seed quality. A single late application at higher labeled rates will improve seed quality. Use pod tests to determine the need for late applications. Use three applications of chlorothalonil in areas having a history of moderate to severe disease intensity. Do not graze or feed treated soybean vines to livestock. Observe days to harvest limit, which varies by product. Reregistration is not being sought for Mertect 340 for soybeans. Consult label before use of this product. Products cannot be used for any crop not specifically listed on label.
Wheat			
Seed rots, seedling blights, loose smut, and bunt (stinking smut)	combinations of of carboxin, thiram, thiabendazole, triadimenol, and captan	 Vitavax many Mertect or TBZ Baytan many	Seed treatment is strongly suggested. Higher labeled rates of carboxin are required for bunt control. Thiram or captan alone will not control loose smut. The combination of carboxin + thiram + thiabendazole is effective when high levels of scab and/or *Septoria* are present.
	PCNB	Terra-Coat	

Table 1. Condensed Disease-Control Recommendations for Field Crops (cont.)

Crop/ Disease	Fungicide or nematicide: Common name	Fungicide or nematicide: Trade name	Comments
Leaf rust, Septoria leaf blotch, Septoria glume blotch, Helminthosporium leaf blight, stem rust, and Pyrenophora tan spot	mancozeb triadimefon	Dithane M-45 Manzate 200 Penncozeb Bayleton	Plant resistant varieties. Apply fungicide when disease conditions warrant. Do not make more than 3 applications of mancozeb and do not apply within 26 days of harvest. Triadimefon is limited to 16 oz of material per season and has a 21 days to harvest restriction. Rotational crops (corn, soybeans, sorghum, and small grains) cannot be planted for 35 days following the last application of triademefon. Do not allow livestock to feed or graze on treated plant materials.
	propicanazole	Tilt	One application per season is permitted at emerging flag leaf stage (Feekes' stage 8). Do not apply after this stage to avoid possible illegal residues. Do not graze or feed livestock-treated forage or cut the green crop for hay or silage. After harvest, the straw may be used for bedding or feed.
Powdery mildew	triadimefon propicanazole	Bayleton Tilt	Plant resistant varieties. Check with your Extension adviser for chemical control recommendations.
Virus diseases Wheat streak mosaic Wheat soilborne mosaic Barley yellow dwarf mosaic Wheat spindle streak mosaic			Plant resistant or tolerant varieties. Plant after the fly-free date. Control volunteer wheat in and around production fields.
Take-all			Plant after the fly-free date. Use ammonium form of nitrogen fertilizer. Use crop rotations of 2 to 3 years between wheat crops where possible.

been properly calibrated for uniform, thorough coverage of all aboveground plant parts. With the equipment now available, a reasonable job of applying fungicides requires a minimum of 5 gallons of water carrier per acre. Superior coverage may be obtained with more water, but the cost may be prohibitive. Conversely, a lower volume (less than 3 to 4 gallons per acre) gives correspondingly poorer control. Five gallons of water can be applied uniformly using about 30 to 70 properly spaced nozzles, depending on the aircraft. The nozzles should be D-8 to D-12, hollow cone, with No. 45 or No. 46 cores. The final decision on nozzle number, size, swath width, and placement depends on the air speed, pressure, and volume desired. Droplet size is also important. Ideally, droplets should be 200 to 400 microns in size for thorough and uniform coverage.

Adjuvants

When it is compatible with the product label, add a spray adjuvant (surfactant) to the spray mix. Adjuvants are suggested to help disperse fungicides and improve coverage when you spray. They are especially helpful for corn and small grains. Some commonly available surfactants are Bio 88, BioFilm, Regulade, Plyac, Triton AG-98, Triton B-1956, Triton CS-7, NuFilm P, NuFilm 17, and DuPont Spreader Sticker (liquid).

Nematicide Application

Granular nematicides/insecticides registered for use on corn, sorghum, and soybeans may be used as in-furrow or band treatments, depending on the product label. In general, band applications have given more consistent control than have in-furrow applications. Follow the manufacturer's suggestions on incorporation. Nematicides should be used only where soil analysis shows an economic problem. They are not designed to replace crop rotation and the use of resistant crop varieties in a management program. Successful nematode management is based upon a combination approach that may include pesticides. However, pesticides alone will not provide adequate control and may produce additional environmental problems. Follow soil sampling instructions in *Report on Plant Diseases* No. 1100, "Collecting and Submitting Soil Samples for Nematode Analysis."

Fungicide Guidelines

Seed Treatments

The greatest benefits of fungicide seed treatments will be found (1) where low seeding rates are used; (2) where seed must be used that is of poor quality because of fungal infection; and (3) where seed is planted in a seedbed in which delays in germination or emergence are likely.

Fungicide seed treatments are not a substitute for high-quality seed and will not improve the performance of seed that is low in quality due to mechanical damage or physiological factors. Treated seed of low quality will not produce stands and/or yields equal to untreated high-quality seed. Therefore, only high-quality seed should be considered for planting.

The following checklist for soybean seed treatments (Table 2) is designed to assist in determining the need for seed treatments, especially for control of damping-off fungi. Selection of the proper seed treatment is very important because of the specificity of certain fungicides for controlling only *Phytophthora* and *Pythium*.

Foliar Treatments

Foliar fungicide treatments may reduce losses in soybeans from Septoria brown spot, Cercospora leaf blight, purple seed stain, anthracnose, pod and stem blight, and stem canker. These diseases are most damaging when the weather is warm (70° to 80°F) and wet from early pod fill to maturity. Foliar sprays of fungicides may increase yields 10 to 15 percent, increase seed quality, and reduce disease losses when such fields are planted to soybeans the following year. The use of fungicides should be based on expected disease severity and are most economical for seed production fields. The six diseases just listed will *not* be as severe in cool, dry seasons and where adequate rotations have been used.

Based on 7 years of research data, soybean yields have been increased by an average of 4.7 bu/A (range, 1.2 to 13.4), and seed quality has been increased by an average of 10.7 percent (range, 0 to 42.5 percent) by the use of foliar fungicides.

The checklist in Table 3 can be used at early bloom to determine if fungicide controls for the six diseases mentioned should be used. A key factor in this checklist is the presence of black specks (pycnidia) on fallen petioles. Only brown, fallen petioles should be assayed, and more than two-thirds to three-fourths of these petioles should show pycnidia. If growers use the checklist and apply fungicides correctly, maximum benefits should be achieved. Less than optimal benefits will be achieved if fungicides are applied incorrectly or if disease severity does not warrant spraying.

Foliar fungicides are also applied to small grains (primarily wheat) to control rusts, Septoria diseases,

Table 2. Soybean Seed Treatment Checklist for Reducing Early Season Stand Losses Due to Damping-Off from *Pythium* and *Phytophthora* Fungi

Risk factors	Point value if answer is yes
Rainfall for the 7-day period before planting was	
Below normal	2
Normal	1
Above normal	4
Seedbed preparation was	
Conventional tillage	1
Rough surface (conservation tillage)	2
No-till	4
Germination at time of planting is less than 85 percent in a warm test or less than 70 percent in a cold test (discard such seed if at all possible)	3
Previous soybean stand in field was reduced by damping-off or Phytophthora root rot	4
Level of resistance to Phytophthora root rot is	
Susceptible	2
Tolerant	4
Resistant to one or more races	1
Expected rainfall for 96 hours following planting is	
Below normal	1
Normal	1
Above normal	3
Low areas of field remain flooded for 48 hours following 1 inch of rainfall	4
Seeding rate is less than 55 pounds per acre	3
Field is planted to double-crop soybeans	3

TOTAL POINTS AND SUGGESTIONS

Fewer than 7 points:
seed treatment will probably not be beneficial.
From 7 through 15 points:
seed treatment may be beneficial if weather conditions do not favor rapid germination and growth.
Greater than 15 points:
seed treatment will be beneficial to stand development.

Table 3. Checklist to Determine Whether Foliar Fungicide Application Should Be Made to Soybeans

If the total point value is 15 or more, application will probably mean increased yields and higher seed quality.

Risk factors	Point value if answer is yes
Rainfall, dew, and humidity up to early bloom and pod set are	
Below normal	0
Normal	2
Above normal	4
Soybeans were grown in the field last year	2 to 3
Chisel-plow, disk, or no-till was used	1
Pycnidia (black specks) are visible on fallen petioles, and Septoria brown spot is obvious on the lower leaves	2
Early maturing variety (not full-season)	1 to 2
Soybeans are to be used or sold for seed	6
Yield potential is better than 35 bushels per acre	2
Seed quality at planting time is less than 85 percent germination in a warm test	1
Other conditions that favor disease development (weather forecast with a 30-day period of greater-than-normal rainfall and a field history of disease)	1 to 3

Helminthosporium leaf blights, and tan spot. These diseases are most damaging when the weather is wetter than normal from emergence of the flag leaf to the early milk stage. Foliar sprays of fungicides may increase yields by 15 to 30 percent and increase both seed weight and quality.

The use of fungicides should be based on the amount of disease at the emergence of the flag leaf. The foliar diseases just listed will *not* be as severe if the heading period is drier than normal and where adequate rotations have been used.

Foliar fungicides are applied to corn—primarily in seed production fields—to control the four Helminthosporium leaf blights and the two rust diseases. The use of fungicides is generally justified only when disease is prevalent within 2 weeks of tasseling.

Disease Reactions of Field Crop Varieties Recommended for Illinois

Disease reactions may vary from one locality to another and from year to year, depending on what physiologic races of the pathogens are present. For the latest information on suggested crop varieties, consult your local Extension office or the Department of Agronomy, University of Illinois, W-201 Turner Hall, 1102 South Goodwin Avenue, Urbana, IL 61801.

Table 4 lists grass varieties which can be grown in Illinois and factors which influence the selection of these varieties. Tables 5 through 10 list varieties of various crops which can be grown in Illinois and the average reaction of these varieties to each of several diseases which affect the crop. For their asistance in preparing Tables 4 through 10, we wish to thank E.D. Nafziger, D.W. Graffis, and G.E. Pepper, all of the Department of Agronomy, University of Illinois, Urbana-Champaign; and W.L. Pedersen, Department of Plant Pathology, University of Illinois, Urbana-Champaign.

Table 4. Grass Varieties Suggested for Illinois and Factors Influencing Their Selection

Species and variety	Endophyte	Helminthosporium and rust diseases	Alkaloid level	Maturity	Winter hardiness
Kentucky bluegrass					
Dormie	NA	-	NA	Early	Hardy
Orchardgrass					
Benchmark	NA	-	NA	Early	Moderate
Crown	NA	Rust resistant	NA	Medium	Hardy
Dart	NA	Rust and Leaf scorch resistant	NA	Medium	Moderate
Dawn	NA	-	NA	-	Moderate
Hawk	NA	Rust resistant	NA	Medium early	Hardy
Hera	NA	-	NA	-	Very hardy
Ina	NA	-	NA	Medium	Hardy
Juno	NA	Good resistance	NA	Early	Hardy
Justus	NA	-	NA	-	Moderate
Pacific	NA	Stem rust resistant	NA	Medium early	Moderate
Phyllox	NA	-	NA	-	Moderate
Potomac	NA	-	NA	Early	Moderate
Rancho	NA	Stem rust resistant	NA	Late	Hardy
Rapido	NA	-	NA	-	Moderate
Perennial ryegrass					
Bison	NA	Good resistance	NA	-	Moderate
Gladiator	NA	-	NA	-	Moderate
Perennial ryegrass x Tall fescue					
Tandem	NA	-	NA	-	Moderate
Perennial ryegrass x Meadow fescue					
Tandem Festulolium	NA	Leaf spot, Crown rust resistant	NA	-	Moderate
Reed Canarygrass					
Flare	NA	-	-	Medium	Hardy
Palaton	NA	Good tolerance	Low	Medium early	Hardy
Vantage	NA	-	Moderate	Medium	Hardy
Venture	NA	-	Low	Medium	Hardy

Table 4. Grass Varieties Suggested for Illinois and Factors Influencing Their Selection (cont.)

Species and variety	Endophyte	Helminthosporium and rust diseases	Alkaloid level	Maturity	Winter hardiness
Rescuegrass					
Matua	NA	-	NA	Early	Hardy
Smooth Bromegrass					
Barton	NA	-	NA	Medium	Hardy
Blair	NA	-	NA	Medium	Hardy
Bravo	NA	-	NA	Medium	Hardy
Fox	NA	-	NA	Medium	Hardy
FS Beacon	NA	-	NA	Medium	Hardy
Lincoln	NA	-	NA	Medium	Hardy
Rebound	NA	-	NA	Moderately late	Hardy
Sac	NA	-	NA	Medium	Hardy
Jubilee	NA	Probably resistant	NA	Medium early	Hardy
Tall Fescue					
AU-Triumph	Low	-	NA	Early	Low
FA-293	-	Leaf spot, Crown rust resistant	NA	Medium	Moderate
Forager	Low	-	NA	Late	Moderate
Johnstone	Low	-	NA	Medium	Moderate
Kenhy	Low	-	NA	Medium	Moderate
Ky-31	-	-	NA	Medium	Moderate
Martin	Low	Excellent resistance	NA	Medium	Moderate
Mozark	Low	Good resistance	NA	Medium	Moderate
Mustang	-	Leaf spot resistant	NA	Medium	Moderate
Phyter	-	Crown rust resistant	NA	Medium	Moderate
Timothy					
Clair	NA	-	NA	Very early	Hardy
Itasca	NA	-	NA	Medium	Hardy
Mariposa	NA	-	NA	Medium	Hardy
Mohawk	NA	-	NA	Late	Hardy
Pronto	NA	-	NA	Medium	Hardy
Richmond	NA	-	NA	Early	Hardy
Timfor	NA	-	NA	Medium	Hardy

- = no information available; NA = not applicable.

Table 5. Public Soft Winter Wheat Varieties Suggested for Illinois and Their Average Reactions to Eight Common Diseases

Several private varieties have high yield potentials and are widely planted. Growers should contact seed company representatives for information on disease resistance.

Variety	Recommended area of state	Stem rust	Leaf rust	Loose smut	Septoria	Powdery mildew	Soil-borne mosaic	Barley yellow dwarf	Wheat spindle streak
Auburn	N, C, S	R	R	MR	R	MR	R	MS	MS
Becker	N, C, S	-	MR	-	MS	S	MR	-	R
Caldwell[a]	N, C, S	R	MR	MR	MS	MR	MR	MR	MS
Cardinal[a]	C, S	MS	MR	-	-	-	-	-	-
Clark	C, S	-	MS	-	MR	MR	R	-	-
Dynasty	N, C, S	-	R	-	-	MR	-	-	-
Howell	N, C, S	MR	S	-	-	S	MR	MR	-
Madison	C, S	MR	MR	-	MR	MR	MR	-	R
Pike	N, C, S	S	S	MR	MS	S	MR	MR	MS
Tyler	S	S	S	-	-	R	R	MR	-
Wakefield	C, S	MS	MS	-	MR	MS	MS	-	MR

Average disease reaction: R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible; - = no information or disease is not important. Area of Illinois where variety is recommended: N = northern; C = central; S = southern.

[a]Moderate resistance to take-all.

Table 6. Public Soybean Varieties Suggested for Illinois and Their Average Reactions to Eight Common Diseases

Growers should contact individual seed companies for information on disease resistance of private varieties.

Variety	Suggested area of the state	Phytophthora rot[a]	Bacterial pustule	Powdery mildew	Pod and stem blight	Soybean cyst nematode (races 3 and 4)		Purple seed stain	Downy mildew	Sclerotinia white mold
Archer[b]	N, C	R-1-9	-	-	-	S	S	-	-	-
Bell	N	R-1-4-7	-	-	-	R	R	-	-	-
BSR 101[b]	N	R	-	-	MS	S	S	MR	-	-
BSR 201[b]	N, C	R	-	-	MS	S	S	-	-	-
Burlison	N, C	R-1-9	-	-	-	S	S	-	-	-
Cartter	C, S	S	-	-	-	R	R	-	-	-
Century 84	N, C	R-1-9	S	-	S	S	S	S	MS	S
Chamberlain[b]	C, S	R	-	-	-	S	S	-	-	-
Chapman	N, C	R-1-9	-	-	-	S	S	-	-	-
Conrad	N, C	S	-	-	-	S	S	-	-	-

Table 6. Public Soybean Varieties Suggested for Illinois and Their Average Reactions to Eight Common Diseases (cont.)

Variety	Suggested area of the state	Phytophthora rot[a]	Bacterial pustule	Powdery mildew	Pod and stem blight	Soybean cyst nematode (races 3 and 4)		Purple seed stain	Downy mildew	Sclerotinia white mold
Delsoy 4210	S	S	-	-	-	R	R	-	-	-
Delsoy 4710	S	S	-	-	-	R	R	-	-	-
Edison	C, S	R-1-9	-	-	-	S	S	-	-	-
Egyptian	S	S	-	VS	S	R	R	S	-	-
Elgin 87	N, C	R-1-9	-	-	-	S	S	-	-	-
Fayette	C, S	S	R	-	-	R	R	MS	-	-
Flyer	S	R-1-9	-	-	-	S	S	-	-	-
Hack	N, C	R-1-2	-	-	S	S	S	-	-	-
Hamilton	S	S	-	-	-	S	S	-	-	-
Harper 87	C, S	R-1-9	R	-	-	S	S	-	-	-
Hobbit 87	C, S	R-1-9	R	-	S	S	S	-	-	-
Jack	-	R-1-4-7	-	-	-	R	R	-	-	-
Kenwood	N, C	S	-	-	-	S	S	-	-	-
Linford	C, S	MS	-	-	-	R	R	-	-	-
Nile	S	S	-	-	-	R	S	-	-	-
Pella 86	C, S	R-1-9	R	-	-	S	S	-	S	S
Pennyrile	S	S	-	-	-	S	S	S	-	-
Pharaoh	S	S	-	-	-	R	S	-	-	-
Preston	N, C	S	-	-	-	S	S	-	-	-
Pyramid	S	S	-	-	-	R	R	-	-	-
Resnik	C, S	R-1-9	-	-	-	S	S	-	-	-
Ripley	S	S	-	-	-	S	S	-	-	-
Sherman	C, S	S	-	-	S	S	S	-	-	-
Spry	S	S	-	-	-	S	S	-	-	-
Union	S	R-1-2	-	-	MS	S	S	-	R	MR
Williams 82	C, S	R-1-9	-	-	-	S	S	S	S	-

Average disease reaction: R = resistant; MR = moderately resistant; MS= moderately susceptible; S = susceptible; VS = very susceptible; - = no information. In the Phytophthora rot column, numbers following R (= resistant) are race numbers to which the variety is resistant. Areas of Illinois where variety is suggested: N = northern; C = central; S = southern.

[a]Races 1 and 2, except where other races are indicated.

[b]Resistant to brown stem rot.

Table 7. Public Barley Varieties Suggested for Illinois and Their Average Reactions to Twelve Common Diseases

Variety	Recommended area of state	Stem rust	Leaf rust	Loose smut	Covered smut	Septoria	Powdery mildew	Barley yellow dwarf	Barley stripe mosaic	Spot blotch	Net blotch	Helminthosporium stripe	Scald
Spring													
Larker	N	MR	S	S	S	S	S	MS	S	S	MS	-	S
Manker	N	MR	S	S	S	S	S	MS	S	MR	MR	-	S
Winter													
Barsoy	C, S	MS	S	S	-	-	MR	S	S	-	MS	S	S
Pike	C, S	MS	S	S	-	-	MR	S	S	-	MR	MR	S
Wysor	C, S	-	R	-	-	MS	R	MR	-	-	MS	-	R

Average disease reactions: R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible; - = no information. Areas of Illinois where variety is suggested: N = northern; C = central; S = southern.

Table 8. Public Oat Varieties Suggested for Illinois and Their Average Reactions to Five Common Diseases

Variety	Recommended area of state	Stem rust	Crown rust	Smuts	Barley yellow dwarf	Septoria
Don	N, C, S	S	R	R	MR	MS
Hazel	N, C, S	S	R	S	R	MS
Lang	N, C, S	MS	S	MS[a]	MR	MS
Larry	N, C, S	MS	S	MS	MR	MS
Noble	N, C, S	MS	S	R	MR	MS
Ogle	N, C	MS	S	MS	MR	MS
Otee	N, C, S	MS	S	MS	R	MS

Average disease reaction: R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible. Areas of Illinois where variety is suggested: N = northern; C = central; S = southern.
[a]Susceptible to new races of smut fungi.

Table 9. Red Clover Varieties Suggested for Illinois and Their Average Reactions to Four Common Diseases

Red clover variety	Northern anthracnose	Southern anthracnose	Powdery mildew	Sclerotinia root rot	Spring blackstem	Summer blackstem
Arlington	R	-	R	-	-	-
Atlas	R	HR	R	-	-	R
E688	T	R	R	-	-	-
Florie	R	R	R	-	-	-
Kenland	S	R	-	-	-	-
Kenstar	S	R	-	-	-	-
Marathon	R	MR	-	-	-	-
Mega	R	R	R	-	-	-
Mor Red	HR	MR	HR	-	-	-
Redland	MR	R	R	-	-	-
Redland II	R	R	R	-	-	-
Redland III	R	R	R	-	-	-
Redman	R	MR	R	-	-	-
Ruby	R	R	-	-	-	-

Average disease reactions: R = resistant; MR = moderately resistant; HR = highly resistant; S = susceptible; T = tolerant; - = no information.

Table 10. Alfalfa Varieties Suggested for Illinois and Their Average Reactions to Eleven Common Diseases and Winterhardiness

	Bacterial wilt	Phytophthora root rot	Aphanomyces	Verticillium wilt	Fusarium wilt	Anthracnose	Sclerotinia	Common leaf spot	Lepto leaf spot	Spring blackstem	Summer blackstem	Winter hardiness
Aggressor	HR	HR	MR	R	HR	R	-	-	-	-	-	MH
AgriBoss	HR	HR	-	MR	HR	HR	-	-	-	-	-	MH
AgriMate	R	R	-	R	HR	R	-	-	-	-	-	MH
Alfagraze	MR	L	-	-	R	MR	-	-	-	-	-	H
Allegiance	R	R	-	R	R	HR	-	-	-	-	-	MH
Americana Acclaim	R	MR	-	LR	R	MR	-	MR	-	-	-	H
Americana Leader	R	R	-	R	R	R	-	-	-	-	-	H
Americana PH2121	HR	R	-	-	R	MR	-	MR	-	-	-	MH
Apollo II	R	HR	-	MR	R	MR	-	-	-	-	-	MH
Apollo Supreme	HR	R	-	R	HR	HR	-	-	-	-	-	MH
Archer	R	R	-	R	R	R	-	-	-	-	-	MH
Arrow	R	HR	MR	R	HR	MR	-	-	-	-	-	H
Asset	HR	HR	MR	R	R	R	-	R	R	-	-	MH
Baker	R	S	-	S	S	L	-	MR	-	-	-	H
Belmont	HR	R	-	R	HR	HR	-	MR	MR	MR	-	MH
Benchmark	HR	HR	R	R	HR	HR	-	T	T	-	-	-
Big Ten	-	-	-	-	-	-	-	-	-	-	-	-
Blazer	R	R	-	-	R	L	-	-	-	-	-	MH
Break-thru	-	-	-	-	-	-	-	-	-	-	-	-
Centurion	HR	R	-	R	R	R	-	MR	L	MR	-	H

Table 10. Alfalfa Varieties Suggested for Illinois and Their Average Reactions to Eleven Common Diseases and Winterhardiness (cont.)

	Bact-erial wilt	Phy-toph-thora root rot	Aphano-myces	Verti-cillium wilt	Fusar-ium wilt	Anth-rac-nose	Sclero-tinia	Com-mon leaf spot	Lepto leaf spot	Spring black-stem	Summer black-stem	Winter hard-iness
Chief	HR	HR	-	R	R	R	-	-	-	-	-	MH
Cimarron	HR	MR	-	L	HR	HR	-	MR	-	-	-	MH
Cimarron VR	HR	MR	MR	MR	HR	HR	-	MR	MR	HR	-	MH
Clipper	HR	R	-	R	HR	R	-	-	-	-	-	H
Comet	R	R	-	R	R	R	-	-	-	-	-	H
Commandor	R	R	-	MR	R	HR	-	R	R	-	-	MH
Crown	R	R	-	R	R	R	-	-	-	-	-	MH
Crown II	HR	HR	-	-	HR	HR	-	-	-	-	-	-
Crystal	HR	HR	L	R	HR	R	-	-	-	-	-	-
Cutter	R	HR	MR	R	HR	R	-	-	-	-	-	MH
Dart	HR	HR	-	R	HR	R	-	-	-	-	-	MH
Dawn	R	R	MR	R	HR	R	-	-	-	-	-	H
Decathlon	HT	MT	-	MT	T	MT	-	-	-	-	-	MH
DeKalb Brand 120	HR	R	-	-	MR	MR	-	-	-	-	-	H
DK122	HR	HR	-	R	R	HR	-	T	-	T	-	MH
DK125	HR	R	S	R	R	HR	-	-	-	-	-	MH
DK135	R	MR	-	MR	R	MR	-	-	R	-	-	MH
Dominator	HR	HR	R	R	HR	HR	-	-	-	-	-	MH
Drummor	R	R	-	-	MR	MR	-	-	-	-	-	H
Duke	HR	H	-	-	HR	MR	-	-	-	-	-	H
Dynasty	HR	R	-	R	R	MR	-	-	-	-	-	MH
Echo	R	R	-	R	R	MR	-	-	-	-	-	-
Eclipse	-	-	-	-	-	-	-	-	-	-	-	-
Edge	R	R	-	R	-	HR	-	-	-	-	-	MH
Elevation	R	MR	-	MR	R	MR	-	-	-	-	-	MH
Eliminator	-	-	-	-	-	-	-	-	-	-	-	-
Embro A-54	R	-	-	-	-	-	-	MR	-	-	-	H
Embro A-79	-	-	-	-	-	-	-	-	-	-	-	-
Endure	R	R	-	R	R	MR	-	-	-	-	-	H
Envy	R	R	-	R	R	R	-	-	-	-	-	-
Epic	R	R	-	-	R	S	-	-	-	-	-	MH
Excalibur	R	L	-	R	HR	MR	-	-	-	-	-	MH
Flagship 75	HR	HR	MR	MR	MR	R	-	-	-	-	-	-
Flint	R	R	-	L	-	HR	-	-	-	-	-	-
Fortress	R	HR	-	R	R	R	-	R	R	-	-	MH
Funk's G-2833	R	R	-	R	R	R	-	-	-	-	-	H
Funk's G-2841	R	R	-	R	-	R	-	-	-	-	-	H
Funk's G-2852	HR	R	-	R	R	HR	-	-	-	-	-	MH
Garst 629	MR	MR	-	MR	R	MR	-	-	-	-	-	MH
Garst 630	HR	R	-	MR	R	MR	-	-	-	-	-	-
Garst 636	R	R	-	R	R	R	-	-	-	-	-	MH
Garst 645	HR	HR	MR	R	R	HR	-	-	-	-	-	MH
GH 777	HR	HR	R	R	HR	R	-	T	T	-	-	-
GH 747	HR	HR	-	MR	HR	HR	-	-	-	-	-	MH

Table 10. Alfalfa Varieties Suggested for Illinois and Their Average Reactions to Eleven Common Diseases and Winterhardiness (cont.)

	Bacterial wilt	Phytophthora root rot	Aphanomyces	Verticillium wilt	Fusarium wilt	Anthracnose	Sclerotinia	Common leaf spot	Lepto leaf spot	Spring blackstem	Summer blackstem	Winter hardiness
Impact	HR	R	-	R	HR	MR	-	-	-	-	-	MH
Invincible Xtra	-	-	-	-	-	-	-	-	-	-	-	-
Jade	HR	HR	-	R	HR	R	-	-	-	-	-	-
Legend	-	-	-	-	-	-	-	-	-	-	-	-
Lewis 788	-	-	-	-	-	-	-	-	-	-	-	-
Lewis 789	HR	R	-	MR	HR	MR	-	-	-	-	-	-
Magnum III	R	R	L	MR	R	MR	-	-	-	-	-	MH
Magnum +	R	R	-	L	-	MR	-	-	-	-	-	MH
Majestic	HR	MR	-	HR	HR	HR	-	MR	L	L	-	H
Mercury	R	HR	-	-	HR	MR	-	-	-	-	-	H
Milkmaker	R	MR	-	S	R	MR	-	-	-	-	-	MH
Mohawk	HR	-	-	-	-	HR	-	-	-	-	-	MH
MultiKing 1	HR	R	-	R	MR	HR	-	-	-	-	-	MH
Multi-plier	HR	HR	-	R	HR	HR	-	MR	R	MR	-	H
New Era 90	-	-	-	-	-	-	-	-	-	-	-	-
Nitro	-	-	-	-	-	-	-	-	-	-	-	NH
Nordic	HR	HR	MR	R	R	HR	-	-	-	-	-	H
Oneida VR	R	MR	-	R	-	S	-	-	-	-	-	MH
Patriot	R	R	-	R	R	R	-	-	-	-	-	-
Perry	R	S	-	-	-	T	-	-	-	-	-	MH
Pioneer BR 5262	HR	R	-	L	MR	S	-	-	-	-	-	H
Pioneer BR 5364	-	-	-	-	-	-	-	-	-	-	-	-
Pioneer BR 5373	HR	MR	-	R	HR	HR	-	-	-	-	-	MH
Pioneer BR 5432	HR	MR	-	R	HR	S	-	-	-	-	-	MH
Polar II	R	R	-	-	-	-	-	-	-	-	-	H
Precedent	HR	HR	R	R	HR	R	-	MR	R	-	-	-
Premier	-	-	-	-	-	-	-	-	-	-	-	-
Promise	-	-	-	-	-	-	-	-	-	-	-	-
PRO-CUT	HR	HR	-	R	HR	R	-	MR	MR	MR	-	-
PRO-CUT 2	HR	HR	-	R	R	R	-	MR	R	MR	-	H
Raidor	R	-	-	-	L	R	-	-	-	-	-	MH
RamRod	-	-	-	-	-	-	-	-	-	-	-	-
Renegade	R	R	-	L	R	T	-	-	-	-	-	H
Riley	HR	S	-	S	-	HR	-	-	-	-	-	MH
Royalty	HR	HR	-	R	HR	HR	-	MR	MR	MR	-	H
Sabre	HR	MR	-	HR	HR	HR	-	MR	L	L	-	H
Saranac AR	MR	S	-	S	-	R	-	MR	L	L	-	H
Shenandoah	R	R	-	-	R	R	-	MR	-	MR	-	MH
Spredor 2	HR	-	-	-	L	S	-	-	-	-	-	H
Stetson II+	HR	HR	-	R	HR	R	-	-	-	-	-	-

Table 10. Alfalfa Varieties Suggested for Illinois and Their Average Reactions to Eleven Common Diseases and Winterhardiness (cont.)

	Bacterial wilt	Phytophthora root rot	Aphanomyces	Verticillium wilt	Fusarium wilt	Anthracnose	Sclerotinia	Common leaf spot	Lepto leaf spot	Spring blackstem	Summer blackstem	Winter hardiness
Stine 9227	HR	HR	MR	R	HR	HR	-	-	-	-	-	MH
Sure	HR	R	-	R	HR	HR	-	-	-	-	-	H
Target II	HR	R	-	R	R	R	-	-	-	-	-	-
Terminator	HR	R	-	R	HR	R	-	-	-	-	-	-
Top Ton	-	-	-	-	-	-	-	-	-	-	-	-
Trident II	HR	HR	MR	R	R	R	-	-	-	-	-	H
Vancor	R	MR	-	-	MR	R	-	-	-	-	-	H
Vector	R	R	-	MR	HR	R	-	-	-	-	-	-
Vernal	R	S	-	S	-	S	-	L	L	L	-	H
Verta +	HR	R	-	R	R	HR	-	-	-	-	-	-
VIP	HR	R	-	MR	HR	R	-	-	-	-	-	MH
Voris New Era 90	-	-	-	-	-	-	-	-	-	-	-	-
Voyager	MR	MR	-	L	-	MR	-	-	-	-	-	-
Webfoot	-	HR	-	-	-	-	-	-	-	-	-	H
Whata 300	R	MR	-	MR	HR	MR	-	-	-	-	-	H
Whata 427	-	-	-	-	-	-	-	-	-	-	-	-
Whata 454	R	R	-	R	R	R	-	-	-	-	-	-
WL 225	HR	HR	-	R	HR	MR	MR	MR	MR	L	L	H
WL 317	HR	HR	L	R	HR	R	MR	MR	MR	MR	MR	H
WL 320	R	R	-	MR	HR	MR	-	T	T	T	-	MH
WL 322 HQ	HR	R	L	R	HR	MR	T	T	T	L	L	MH
Wrangler	R	HR	-	L	R	L	-	-	-	-	-	H
Wyffels Premier	R	HR	-	R	HR	HR	-	T	T	T	-	H
Wyffels WA-2	HR	R	-	MR	R	MR	-	-	-	-	-	MH
Zenith	HR	HR	-	R	HR	HR	-	-	-	-	-	-

Average disease reaction: HR= highly resistant; R = resistant; M = moderately resistant; L = low resistance; S = susceptible; T = tolerant; MH = moderately hardy; H = hardy; NH = nonhardy; - = no information.

7

Controlling Rodent Damage in Conservation Tillage Systems

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There is considerable concern among farmers who practice conservation tillage that rodents will become a serious problem because of the increased amount of vegetation or "rodent cover" left on the surface of the soil. However, one should not assume that rodents, in general, will become significant economic pests in all fields under conservation tillage. Whether rodent populations will increase and cause economic damage in a particular cornfield depends on many conditions. The species of rodent, phase of the rodent's population cycle, reproductive condition of the rodents, past history of the field, type of edge surrounding the field, weather conditions, and several other factors all affect the potential for rodent damage.

Of the various types of conservation tillage operations, *no-till* and *cover crop operations* are probably the best candidates for damage caused by rodents. The large amounts of vegetation change the habitat structure, and the lack of tillage allows undisturbed establishment of rodent burrows. Damage occurs in these fields after herbicide applications destroy much of the food resource of the rodents, which often turn to corn seeds and young plants as an alternate food source.

The rodents that can cause damage to corn in Illinois include:

1. Deer mouse *(Peromysus maniculatus)*
2. House mouse *(Mus musculus)*
3. Prairie and meadow voles (*Microtus* spp.)
4. Thirteen-lined ground squirrel *(Spermophilus tridecemlineatus)*

Mice and Voles

Deer Mice and White-footed Mice

These two mice are very similar in biology and behavior, and it is very difficult for a layperson to distinguish between them. Both deer and white-footed mice are small with large protruding eyes, long coarse whiskers, and a bicolored furry tail one-third to one-half of the animal's total length. The upper body color varies from slate gray to a golden brown. The belly area and feet are white. The total length of deer and white-footed mice is between 5 and 6 inches (12.7 and 15.2 cm). Both species produce an average of four litters a year containing four mice per litter. Once established in a crop area, these mice may inhabit both the open fields and brushy areas of the crop and may become abundant in corn, wheat, and soybean fields.

House Mice

The common house mouse is also found in crop fields. This mouse requires vegetative cover and is therefore more likely to be found in weedy edges or reduced tillage fields. The house mouse is approximately the same size as the deer mouse, but the entire body is a uniform dull gray.

Also, the tail is not bicolored and furred, but rather seminaked with only sparse hairs. House mice are capable of producing eight to ten litters per year with four to six young per litter.

Voles

Voles are easily distinguished from other small field rodents by their short tails, which are one-half of their total length, and by their short, hairy ears, which hardly project above the fur. Adult voles average about 6 inches (15.2 cm) in length and are robust-bodied with long, soft fur. Color may vary seasonally, but normally the fur is chestnut brown (head, back, and sides) and grayish brown (belly).

Voles can produce up to five or six litters per year, averaging about eight young per litter. Vole infestations in good habitat such as alfalfa will normally begin as small isolated colonies on grassy borders adjacent to crop acreage. As vole populations increase, the young adults move into the crop area. Voles will usually have a network of 1.5-inch wide (3.8 cm) runways that are connected with shallow underground burrows.

Damage

Deer, white-footed, and house mice occasionally damage corn and soybean crops when they dig up and consume the seed or nibble on the plants themselves. These mice may also become nuisances during autumn when they feed continuously on stored corn.

Voles are less of a problem pest in corn and soybean fields, but they may be more troublesome in winter wheat and alfalfa fields. Voles will feed on both the tops of alfalfa plants and the roots.

Sampling Method

To determine the presence of field mouse populations, inspect the affected area for mouse burrows and runways. Also inspect for signs of mouse activity in areas such as grassy borders adjacent to the crop, weedy ditch banks, roadside and railroad rights-of-way, and randomly selected spots within the field itself. *Scout the field a few weeks before planting.*

Mouse burrows measure 1.5 to 2.0 inches in diameter and are easily seen. Runways are about 1.5 inches wide and cut through vegetation, connecting the underground burrows. If burrows and runways are abundant, control efforts should be initiated before planting.

Management Guidelines

Cultural Control

Cultural practices can affect field mouse populations significantly. Clean cultivation and weed control along crop borders, fencerows, roadsides, and ditch banks are important preventative measures. These areas provide excellent mouse harborage from which wintering mouse populations can expand rapidly and emigrate to crop areas after planting.

Alternative Feeding

There is evidence that alternative feeding may be effective in reducing bird and rodent damage to newly planted corn in reduced or no-tillage fields. This procedure involves scattering grain such as corn or wheat on the soil surface around planting time.

Research concerning alternative feeding has been conducted in Illinois primarily for control of voles. The most critical time to prevent vole damage in no-till corn is during the 21 to 28 days after planting. If alternative feeding with baits is to be effective, the bait must be at least as attractive as the planted seed corn; should be applied before planting so the voles will be attracted to it before they locate the planted seed corn; should be applied in a sufficient amount to feed the vole population for at least 21 days; and should be applied evenly across the field. Feed grains like shelled or cracked corn, wheat, or oats are all possible alternative baits.

Guidelines for this program include scouting for active vole colonies about one week before planting. If more than five colonies per acre are active, plan to apply an alternative bait. Apply the bait mixed with dry fertilizer (this saves a trip across the field) within two days before planting. Make certain the vegetation is dry when the bait is spread so that the bait can fall freely to the ground. Use bait that is free of weed seed.

The amount of bait per acre that should be applied is debatable. Previous recommendations were to broadcast six bushels of shelled corn per acre. However, recent research indicates that two bushels of whole kernel corn or four bushels of cracked corn may be equally effective if the vole population is not intense. Scouting should help determine the amount of bait necessary. Intense vole populations may require the application of larger amounts of bait.

Chemical Control

Seed repellents containing methylcarbamate used for repelling birds from corn seed are also very effective against rodents. But the availability of these repellents has been inconsistent during the past few years. Check with local agricultural chemical suppliers or crop consultants concerning the availability and current label status of these products.

Poison baits (for example, zinc phosphide) are available for rodent control in crop areas, but they cannot be applied while the crop is growing. Check with local agricultural chemical suppliers, the USDA Animal Damage Control State Office, your local Extension office, or crop consultants concerning the availability of poison baits for rodent control.

Ground Squirrels

The thirteen-lined ground squirrel *(Spermophilus tridecemlineatus)*, often called a "striped gopher," derives its name from the thirteen alternating light and dark stripes on its back. Adult ground squirrels are about 11 inches (28 cm) in length and have a body weight that varies between 4 ounces (113.4 g) in early spring to nearly 9 ounces (255 g) just before they hibernate in the fall. Thirteen-lined ground squirrels can be distinguished from tree squirrels by their shorter and less bushy tails and the fact that they live in the ground and are not good climbers. They most closely resemble chipmunks, but chipmunks do not have the thirteen stripes and are smaller in size.

Damage

The food of ground squirrels consists of various weed and plant seeds (for example, corn seeds), insects, and leafy vegetation. When they are numerous, ground squirrels can do significant damage to corn and other crops. Ground squirrels dig up planted seeds and consume emerging sprouts. Considerable amounts of seed may be taken because ground squirrels are able to gather the seeds and store them in their cheek pouches to be carried off and buried in shallow caches or stored in their burrows. Damage to crops typically occurs in areas near fencerows, grassy borders, roadsides, and such.

Management Guidelines

Ground squirrels can be controlled using traps, gases, and poison baits.

Gas cartridges used against woodchucks are also effective against ground squirrels. When ignited, these cartridges release carbon monoxide into the burrow system, killing ground squirrels. Gas cartridges are available from local farm supply stores, some county Extension offices, and the U.S. Fish and Wildlife Service.

Gas cartridges should be used as follows:

1. Locate the burrow opening (identified by a mound of fresh excavated soil).

2. With a spade, cut a clump of sod slightly larger than each opening. Place the sod near each entrance.

3. To prepare the gas cartridge for ignition, follow the written instructions on the label.

4. Kneel at the burrow opening, light the fuse, and immediately place (do not throw) the cartridge as far down the hole as possible. Gas cartridges are not bombs and will not explode. A long stick can be used to aid in pushing the cartridge deep into the burrow.

5. Immediately after placing the cartridge in the burrow, close the main opening by covering it with the piece of precut sod, grass side down, to prevent smothering the cartridge with dirt.

6. Stand by for three to four minutes and watch burrow holes. Seal holes if smoke is escaping.

7. Repeat these steps until all burrows in and around problem areas have been treated.

Avoid prolonged breathing of gas cartridge smoke. Also, because sparks may be thrown, gas cartridges should not be used near buildings or any combustible materials.

For best results, treat burrows on cold, rainy days or during periods of inactivity on other days. Because vacant burrows may be reoccupied by ground squirrels from adjoining areas, all fumigated burrows should be rechecked weekly for one month. Any reoccupied burrows should be retreated. Do not fumigate after September because most ground squirrels will be in hibernation and the hibernating chamber is often "walled off," rendering a fumigation treatment ineffective.

Poison baits containing zinc phosphide are also effective against ground squirrels. But these baits can be applied only to noncrop areas such as fencerows, weedy noncrop borders, roadsides, and so forth. Baits cannot be applied where plants are grown for food or feed. Check with local agricultural chemical suppliers, the USDA Animal Damage Control State Office, your local Extension office, or crop consultants concerning the availability of poison baits for ground squirrel control.

Trapping is also an effective method of controlling ground squirrels, but it is only practical when there are just a few squirrels posing a problem. Either number 0 steel traps or a regular wood-base snap trap used to trap rats can be used. Traps should be placed in shallow depressions near the burrow entrances and lightly covered with dry dirt. Squirrels can be lured into the traps by sprinkling small amounts of grain on the earth covering them. Traps should be secured to prevent them from being dragged into the burrow.

Alternative Feeding

Research concerning this practice has been conducted in Illinois primarily for control of voles. See discussion on page 140 for details.

8 Insect Pest Management for Stored Grain

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Important Updates for 1993

- *Reregistration plans for malathion will include some stored grain uses; see p. 147.*
- *Diatomaceous earth: benefits and drawbacks; p. 150.*

Grains produced in Illinois may be stored for periods of a few weeks to a few years before feeding or processing. The profitability of such storage depends not only upon marketing concerns, but also upon maintenance of grain quality. The harvest and storage of grain does not signal an end to the possibility of losses caused by insects and pathogens.

Successful management of stored-grain insects is possible only when proper storage practices are carried out. Insecticides and fumigants should be viewed as supplements to, not replacements for, sound storage methods. Used properly, however, insecticides and fumigants can help to limit insect losses in stored grains without endangering the pesticide applicator or resulting in excessive pesticide residues that threaten the health of consumers (livestock or humans) of treated grain or grain products.

This chapter provides recommendations for cultural and chemical control of stored-grain insects. It is revised annually; always use the current year's *Handbook.* Registration changes that occur between revisions will be announced to appropriate media sources and county Extension offices.

Using Insecticides and Fumigants

The U.S. Environmental Protection Agency (USEPA) has designated certain pesticides for "restricted" use. The fumigants aluminum phosphide, chloropicrin, and methyl bromide are restricted-use pesticides. *Commercial* applicators must be certified in order to apply restricted-use pesticides. Elevator employees responsible for grain treatment at their place of employment must be certified under the category "Grain Facility Pest Control Applicator." Commercial fumigation professionals who treat stored grain or grain products at farms, elevators, warehouses, must be certified by the Illinois Department of Public Health. A *private* applicator who wishes to purchase or apply restricted-use pesticides "for the purpose of protecting any agricultural commodity on property owned or rented by him or as exchange labor (no compensation) on the property of another" must obtain certification by passing an examination administered by the Illinois Department of Agriculture. *Regulations recently enacted by the Illinois Department of Agriculture mandate that private applicators must obtain special certification to purchase and apply grain fumigants To obtain certification for fumigant application, individuals must first pass the private applicator exam and the pass a grain storage and fumigation exam. For information on training materials and examinations, contact the Office of Agricultural Entomology, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820.*

Those who apply pesticides should be aware that the pesticide user is always responsible for the results of pesticide applications. To avoid accidents and maximize the effectiveness of any application, always read the pesticide label and follow all directions and safety

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

precautions. Be sure that the pesticide is specifically labeled for the pest, site, and application method planned. *The label is the law.*

The Poison Information Resource Centers listed in Appendix A have been established to provide information about the treatment of poisoning cases; consult them for help with a poisoning emergency.

Insects Attacking Stored Grain

Several types of insects inhabit stored grain. Exact identification of these insects often is difficult because most stored-grain pests are extremely small (1/16 to 1/4 inch in length), and many separate species are very similar in appearance. Information on the identification of the many species of stored-grain insects is not presented here; materials containing such information are included in the reference listing at the end of this chapter. It is important, however, to recognize the different groups of insects that live in stored grains because management considerations may differ according to the insects' characteristics.

Weevils and Other Insects That Feed Inside Kernels

The most damaging insect pests of stored grain are those that develop within grain kernels. These insects are referred to as internal pests or primary pests. Adults deposit eggs on or in whole kernels, and larvae develop hidden within kernels. Damage caused by internal pests makes grain more suitable for infestation by insects that feed externally on grain or grain debris.

The common primary, or internal, pests of grains in Illinois are the weevils—rice weevil, maize weevil, and granary weevil. The grain weevils are small (between 1/16 and 1/8 inch in length), but recognizable as a group because the head bears a prolonged snout. Another primary pest found in wheat, but only rarely in corn, is the lesser grain borer. Recognition of this pest is possible because the adult lesser grain borer's head projects downward, not forward, from the anterior portion of the body. These insects may be found in any portion of the grain mass within a bin; they are not restricted to portions near the surface.

The larval stages of the Angoumois grain moth also feed within grain kernels. This insect can infest grain in the field; storage infestations are limited to near the surface of the grain mass.

Beetles That Develop and Feed Outside Grain Kernels

Most insects commonly collected in stored grain in Illinois are beetles that range in size from 1/16 inch to over 1/2 inch in length. Adults of most species are reddish brown to black in color, and their forewings are hardened to form a "shell" over the body. Larvae of common species are cylindrical and cream-colored; some bear fine hairs. Species frequently collected in Illinois grain bins include the sawtoothed grain beetle, flat grain beetle, rusty grain beetle, foreign grain beetle, hairy fungus beetle, larger black flour beetle, red flour beetle, and confused flour beetle.

Like the weevils, beetles that feed and develop outside grain kernels are not limited in distribution to the grain surface but instead inhabit any portion of a grain mass. They feed on several different grains, but their buildup in any grain usually results from an abundance of broken kernels (fine material) or fungal growth on moist grain. Their dependence on fines or fungal growth accounts for the description of these insects as "secondary" pests, "bran bugs," or "fungus feeders." Concentrations of stored-product beetles cause an increase in grain moisture and temperature, and such changes favor continued population growth.

Surface-Feeding Caterpillars

Caterpillars that feed in stored grain inhabit primarily the outer portions of the grain mass (usually the grain surface, but also the bottom of the grain mass just above perforated drying floors or aeration ducts). These caterpillars reach approximately 3/4 inch in length and are cream colored. They produce fine, silken webbing as they move about near the grain surface. Mature larvae pupate within a silky cocoon. Adult moths fly and mate in the bin headspace where they may be seen resting on the bin walls and roof.

The Indianmeal moth is the most common surface-feeding caterpillar in stored grain in Illinois. The adult Indianmeal moth has a wingspan of about 3/4 inch; the outer half of each front wing is reddish brown or copper colored. Malathion resistance appears to be common in Illinois populations of Indianmeal moth. Other surface-feeding caterpillars include the Angoumois grain moth (which feeds within kernels), the Mediterranean flour moth, and the meal moth.

Other Stored-Grain Insects

Additional pests that sometimes infest stored grains include psocids (booklice) and grain mites. These soft-bodied pests feed on grain-rotting fungi. An abundance of psocids or grain mites often indicates a more important problem of mold related deterioration of the grain.

Remember that not all insects in grain are pests. Parasitic wasps, larvae of a predaceous fly species, and predaceous Hemipterans (true bugs) attack certain grain pests. In addition, many field insects are inadvertently transported to grain bins, where they cause no damage.

Preventing Insect Infestations

Sources of Infestations

Some stored-grain insects can infest maturing grain crops in the field. Although some field infestations probably occur in Illinois, the extent of field-originated storage problems appears to be minor.

The most common sources of stored-grain insects are old grain, grain spills, feeds, seed, and grain debris. Insects often move to new grain from carry-over grain, from small amounts of grain not cleaned from "empty" bins, from feed supply buildings, and from grain debris beneath perforated floors of bins. Most pest species can fly at least short distances to reach new grain.

Sanitation

To minimize the migration of stored-product insects from current food sources to new grain, thorough cleanup practices are necessary. At least 2 weeks before storing new grain, clean all grain and grain debris from within and around grain bins. Be thorough; sweep or vacuum bin floors. Also remove and feed or destroy any grain and grain debris in combines, wagons, and augers. If grain debris is not removed from the combine, collect and feed or destroy the first few bushels of grain that pass through the combine.

Bin Sprays and Empty-Bin Fumigation

Insects may remain in certain bin locations even after a thorough cleanup is completed. Hard-to-clean sites that harbor insect pests include cracks and crevices in bin walls and the plenum beneath nonremovable perforated floors. Applying an insecticide or a fumigant in an empty bin can supplement (but not replace) physical cleanup efforts.

Apply an insecticide to the walls, ceiling, roof, and floor of all bins that will be used to store grain for more than a few weeks during warm weather. Use:

- 10 fl oz malathion 57% EC in 2 gal water; or
- 1 qt methoxychlor 25% EC in 2 gal water; or
- 12 oz methoxychlor 50% WP in 2 gal water; or
- 4 fl oz Reldan 4E (chlorpyrifos-methyl) in 3 gal water; *do not apply Reldan to bins that will be used to store corn or soybeans;* or
- 8 ml Tempo 2 (cyfluthrin) in 0.26 to 4.2 gal water per 1,000 sq ft (See product label.)
- 1 lb Insecto dust (diatomaceous earth) per 1,000 sq ft (See product label.)

Although Reldan labels call for empty-bin sprays and do not specify the commodity to be stored in treated bins, no legal tolerance has been established for Reldan (chlorpyrifos-methyl) on corn, soybeans, or the products derived from them. Consequently, Reldan should not be used as an empty-bin treatment for bins intended to hold these commodities.

Unless labels specify otherwise, spray all bin surfaces to the point of runoff, and be sure to thoroughly treat all cracks and crevices and areas around doors. Tempo (cyfluthrin) application should not exceed the point of runoff; neither Tempo nor methoxychlor should be applied directly to any grain. Directing extra spray to and through perforated flooring will provide some control of insects living in grain debris in the subfloor plenum, but satisfactory control of insects in this space may require fumigation (or removal of the false floor to allow complete cleanup of debris in the plenum). Insecto (diatomaceous earth) is to be applied by adding the dust to the aeration stream while the fan is pushing air through the plenum and the bin. This application method should deposit significant amounts of diatomaceous earth in the subfloor plenum, but data are lacking on the effectiveness of this application in actual storages.

Fumigating empty bins to control insects in the subfloor plenum may be necessary if summer-harvested grain (wheat, for example) is to be stored in the bin 1 month or longer or if fall-harvested crops (corn, soybeans, or grain sorghum) will be stored beyond May or June of the year following harvest. Empty bin fumigation is usually not necessary where grain will be treated with a protectant insecticide at the auger as it is binned. The fumigant chloropicrin (trade names are Chlor-o-pic, Larvacide 100, and Quasar) is labeled and effective for empty bin fumigation.

Chloropicrin is a restricted-use pesticide that is extremely toxic. The USEPA recently revised fumigant regulations to require the use of a canister respirator (gas mask) or self-contained breathing apparatus if applicators are exposed to chloropicrin. Fumigators also must measure fumigant gas concentrations to determine that the fumigant has dissipated sufficiently before unprotected persons can enter the fumigated space. Follow specific label directions concerning respiratory protection equipment and gas detection devices. Failure to follow all label instructions is unsafe and illegal. If you are uncertain about the safe use of a fumigant, contact the manufacturer for detailed recommendations.

Use chloropicrin only on relatively calm days when the outside air temperature is 65°F or higher. Before applying chloropicrin, use tape and polyethylene sheeting to seal the side door and all bin openings below the level of the side door. Be sure to seal fan openings and the unloading auger shaft. Post warning placards according to label directions. Always have a partner present when applying this or any other fumigant.

To fumigate the subfloor plenum of empty bins, pour in chloropicrin from a ventilation door on the bin roof. Wear a canister respirator equipped with a fresh canister when applying chloropicrin and climbing down from the bin roof. Use 1 quart per 250 square feet of floor area. Chloropicrin forms a pungent tear gas that settles in the lower portion of the bin. This gas will kill all stages of stored-grain insects beneath the subfloor, but chloropicrin will not spread to the upper portions of the bin to kill insects suspended in grain debris remaining on bin walls. Wait at least 24 hours before airing out the bin.

Filling the Bin

Effective insect management in stored grain requires good grain storage practices. Use a grain cleaner to minimize the amount of fine material that is binned along with the grain. Many species of stored-grain insects cannot survive in the absence of broken kernels and grain debris. Use of a grain spreader evenly distributes remaining fine material and helps to level the grain surface. Once the bin is full, if fine material is concentrated in a central core beneath the auger spout, removal of one or a few loads from the bin will extract this core of fines. Periodic removal of the center core during the bin-filling process is even more effective for extracting fines. Do not add new grain on top of old because insects will move from the infested grain to the new crop. Do not overfill bins; the leveled grain surface should be at least a few inches below the lip of the bin. Leveling the grain surface is important for uniform air flow and for effective insecticide or fumigant application.

Store only dry grain. Maintaining moisture levels that prevent the growth of storage fungi is sufficient where fall-harvested grain is to be stored only through the winter, but grains that will be stored 1 month or longer during warm, summer weather should be dried to 12 to 13 percent moisture. This moisture content is unfavorable for most grain insects; it also allows prolonged persistence of protectant insecticide residues.

Aerate to cool stored grain as soon as possible. Temperatures below 50°F prevent insect feeding and reproduction. Cooling grain to just above freezing will kill some stages of many grain insects. Aeration also results in uniform temperatures that prevent moisture migration problems within a bin. Most grain storage references recommend aerating to maintain grain temperatures within 15°F of average outdoor temperatures. These references usually discourage the use of aeration to cool grain below freezing.

Grain Protectants

Application of insecticides directly to grain to prevent insect infestation is warranted if grain is to be stored more than 3 to 6 weeks at grain temperatures above 60° to 70°F. Summer-harvested grains that are to be stored 1 month or more and fall-harvested grains that are to remain in storage beyond May or June of the year following harvest should be treated with a protectant insecticide. Incorporating a surface treatment is adequate for short-term protection. However, uniform application to all grain at the auger is necessary for long-term protection. Where grain protectant insecticides are applied at labeled rates, grain can be processed or fed to livestock with no waiting period.

To protect against stored-grain beetles and weevils throughout the entire mass of grain within a bin, a protectant insecticide must be applied to grain as it is augered into the bin. Drip-on or spray-on applicators can be mounted on the auger to apply liquid formulations. Dusts can be applied using an auger-mounted applicator, or they can be spread over a truck or wagon just before unloading. Protectant insecticides should not be applied to grain before high-temperature drying. Once grain is in the bin, surface "topdressing" or "cap-off" applications of protectant insecticides are effective only against the insects that are feeding at the grain surface. A topdress or cap-off treatment may be used to give some control of insects entering the top of the grain mass. Surface treatments often provide adequate protection where previously uninfested grain is to be stored at warm temperatures for a month or two. For longer storage at warm temperatures, adequate control often requires treating the entire grain mass at the auger as the grain is binned. Table 1 summarizes uses for registered grain protectants.

Crop-specific recommendations for the use of protectant insecticides are:

Corn

It is not necessary to apply any insecticide to new-crop corn that will be removed from storage by May or June of the following spring. Similarly, if corn will be used on site as livestock feed (and not subject to grading associated with sale) within 1 year of harvest, use of a protectant insecticide usually is not necessary. For storage periods of 1 year or longer, apply Actellic or malathion at the loading auger using rates listed in Table 1. Reldan is not registered for use on corn. Do not apply insecticides before high-temperature drying because extreme heat will result in rapid volatilization and reduction in residues. For malathion residues to persist on corn at effective levels through the summer following harvest, corn must be dried to approximately 12 percent moisture. Data indicate Actellic residues will persist for a similar period on grain stored at 14 percent moisture.

Malathion will not control Indianmeal moth. Where malathion is applied at the auger as corn is binned, incorporate *Bt* in the top 4 to 6 inches of the grain once the bin is filled and leveled or by May of the following spring to prevent infestation by Indianmeal moth larvae. Diatomaceous earth may also be used as a topdress treatment to prevent infestation by Indianmeal moth larvae. The use of dichlorvos resin strips in corn bins will be discussed later in this chapter.

Long-term storage programs usually allow "rotating" corn in storage—shipping out old corn and replacing it with the new crop each year. Annual rotation of stored corn helps to avoid buildup of insect infestations. Where annual rotation is practiced, topdress treatments of malathion plus *Bt* or Actellic alone applied in April or May usually provide adequate control without treating the entire grain mass.

Soybeans

Only the Indianmeal moth will infest soybeans stored at moisture levels that prevent mold growth. To protect against Indianmeal moth infestation, rake in surface applications of *Bt* or diatomaceous earth once the bin is filled and leveled or by May of the following year. Dichlorvos resin strips can also be used in soybean bins; see section on Dichlorvos below. No other protectant insecticides are registered for application to stored soybeans.

Wheat

Wheat is especially vulnerable to insect infestation because it is harvested in midsummer when stored-product insects are active within and outside storage facilities. Warm temperatures in summer-harvested wheat also contribute to the rapid development and reproduction of insects within bins.

Apply malathion or Reldan at the loading auger to all wheat that is to be stored for 1 month or more. Where malathion is used, also incorporate *Bt* or diatomaceous earth in the top 4 to 6 inches of grain or use dichlorvos strips (a discussion follows) to prevent Indianmeal moth infestations. Reldan controls Indianmeal moth and the weevils and "secondary" beetles that infest grain. Reldan is not effective against the lesser grain borer. The lesser grain borer's tolerance to common protectant insecticides makes fumigation necessary where it is present.

Sorghum

For storage periods of 1 year or longer, apply Actellic, malathion, or Reldan at the loading auger, but not before high-temperature drying. For malathion residues to persist at effective levels through the summer following harvest, grain must be dried to 12 percent moisture content; Actellic and Reldan should persist for 12 months or more on 14 percent moisture sorghum. Where malathion is applied, also use dichlorvos resin strips or rake in surface applications of *Bt* or diatomaceous earth once the bin is filled and leveled or by May to control Indianmeal moth. Where sorghum has not been treated at the auger as it was binned, topdress applications of Actellic, Reldan, or malathion plus *Bt* usually will provide adequate protection for one summer's storage if application is made by April or May.

Insecticide Resistance in Stored Grain

Insecticide resistance is an important worldwide problem that is especially common (on an international scale) in stored-product insects. In Illinois, resistance to malathion is widespread among Indianmeal moth populations throughout the state. Some Illinois populations of the red flour beetle are resistant to malathion, but the range and intensity of this resistance problem in Illinois are not well known. Populations of the hairy fungus beetle collected in northern Illinois are resistant to both Actellic and malathion; the geographical range of resistant populations of this species is not known.

Reregistration of Malathion

The USEPA has requested from manufacturers new information on malathion's persistence, environmental fate, and mammalian toxicity. Such data are needed to allow reregistration of pesticides that were initially approved under standards no longer considered to be adequate. Because generating the necessary data is very expensive, manufacturers of malathion originally decided not to conduct the studies required for its continued use on stored grains. Recently Cheminova, the major basic manufacturer of malathion, reversed that decision and has announced plans to conduct

Table 1. Insecticides Registered for Use to Protect Stored Grain

Grains treated with protectant insecticides at labeled rates as specified below can be fed to livestock or processed for feed or food uses with no waiting period.

Insecticide	Registered for use on:	Rate/1,000 bu	Restrictions; comments
Malathion 57% EC, 6% D, 4% D, and 2% D	Corn, wheat, oats, barley, rye, sorghum, sunflower	1 pt 57% EC in 2 to 5 gal water; 10 lb 6% dust; 15 lb 4% dust; or 30 lb 2% dust. Use the same amount/ 1,000 sq ft of grain surface as a "capoff" treatment *if the entire grain mass is not treated.*	Do not apply to soybeans. *Malathion will not control Indianmeal moth.* Dry grain to 12% moisture in order for malathion to persist for 1 year or more. Do not apply prior to high-temperature drying. Cap-off treatments do not provide control of insects already active beneath the treated layer.
Chlorpyrifos-methyl (Reldan 4E, 3% D)	Wheat, oats, barley, sorghum	Barley—9.2 fl oz; oats—6.2 fl oz; sorghum—10.7 fl oz; wheat—11.5 fl oz. Apply in 1 to 5 gal water. Use 10 lb 3% dust/1,000 bu. Use 1.6 to 3.0 fl oz 4E or 7 lb 3% dust/1,000 sq ft of grain surface as a "cap-off" treatment *if the entire grain mass is not treated.*	Do not apply to corn or soybeans. Controls weevils, secondary beetles, and Indianmeal moth. Not effective against lesser grain borer. Dry grain to 14% moisture in order for chlorpyrifos-methyl to persist for 1 year or more. Do not apply prior to high-temperature drying. Cap-off treatments do not provide control of insects already active beneath the treated layer.
Bacillus thuringiensis (Bactospeine,Dipel, Di-Wurm D, Top Side Dipel, Thuricide, and others.)	Corn, soybeans, wheat, oats, barley, rye, sorghum, sunflower	Rate depends on product concentration. Follow label directions.	Use to control Indianmeal moth larvae. Controls only larval stages; must be ingested. Apply to top 4 to 6 inches of grain as it is augered in the bin or incorporate by raking when bin is filled.

Table 1. Insecticides Registered for Use to Protect Stored Grain (cont.)

Insecticide	Registered for use on:	Rate/1,000 bu	Restrictions; comments
Pirimiphos-methyl (Actellic 5E)	Corn (including popcorn), sorghum	8.6 to 11.5 fl oz in 5 gal water. Use 3 fl oz in 2 gal water/1,000 sq ft surface area as a "cap-off" treatment *if the entire grain mass is not treated.*	Do not apply to soybeans, wheat, barley, or oats. Controls weevils, secondary beetles, and Indianmeal moth. Dry grain to 14% moisture for pirimiphos-methyl to persist for 1 year or more. Do not apply before high-temperature drying. Cap-off treatments do not provide control of insects active beneath the treated layer.
Diatomaceous earth	Corn, wheat, oats, barley, rye, sorghum, soybeans, sunflower	Follow label directions.	See text, p. 150.
Methoprene (Diacon, 65.7% a.i.)	Corn, wheat, sorghum, barley, oats	Wheat—7.7 fl oz; corn and sorghum —7.1 fl oz; barley—6.1 fl oz; oats—4.1 fl oz. Apply in 5 gal water.	Do not apply to soybeans. Prevents normal development of immature insect stages but will not kill adults. Apply as a preventative, but only once per crop. Not widely available.
Pyrethrins plus piperonyl butoxide	Corn, wheat, oats, barley, rye, sorghum, sunflower	Rate depends on product concentration. Follow label directions.	Do not apply to soybeans. Short-term residual activity. Useful mainly as a surface spray or aerosol to control larval and adult Indianmeal moths as well as other pests at the grain surface.
Dichlorvos resin strips	Corn, soybeans, wheat, oats, barley, rye, sorghum, sunflower	One strip/1,000 cu ft of headspace	See text; p. 150.

necessary trials and pursue reregistration of malathion for at least some uses on stored grains and in storage facilities. As this process continues, farmers and elevator operators may use available supplies of malathion on stored grains according to existing label directions in 1993. Changes in malathion's registration will be reported in the 1994 issue of this *Handbook.*

Dichlorvos

Resin strips containing the insecticide dichlorvos (DDVP, Vapona) have been used for several years in grain storages primarily to control the adult Indianmeal moth in the storage headspace. Originally known as "No-Pest Strips," these insecticide devices have been sold under several trade names. As a result of studies commissioned by the National Toxicology Program, the USEPA classified dichlorvos as a probable human carcinogen and initiated a "Special Review" of dichlorvos to evaluate data on its toxicity and the benefits and risks associated with its use in a variety of pest control situations. In 1989, the Special Review resulted in downgrading the risk classification of dichlorvos to that of "possible" human carcinogen. Most approved uses, including the use of impregnated strips in grain storages, were not modified. Although dichlorvos strips are again available through many pesticide distributors, grain managers are advised to consider possible health risks and public concern before resuming widespread use of dichlorvos resin strips.

Methoprene

The USEPA recently approved registration of the insect growth regulator methoprene (trade name Diacon) for use on stored grains (but not soybeans). Methoprene is a compound similar to the naturally occurring juvenile hormones of insects. Its acute toxicity to mammals is very low. The active ingredient methoprene interferes with the growth and maturation of immature stages of insects. It will not control adult insects already present in grain, but it will prevent immature stages from developing to adults and reproducing. Insects listed on the Diacon label include the Indianmeal moth, cigarette beetle, lesser grain borer, sawtoothed grain beetle, merchant grain beetle, red flour beetle, and confused flour beetle.

Initial labeling for Diacon allowed its use as an empty-bin spray and as a direct spray on grain as it is augered or conveyed into storage; no instructions for surface topdress application were included on the Diacon label. Because methoprene does not kill adult insects, it does not provide rapid control of existing infestations.

Despite its recent registration, Diacon has not been marketed widely. This product will probably not be available in 1993.

Diatomaceous Earth

Diatomaceous earth is an abrasive and slightly sorptive dust that damages an insect's body covering and causes death by dehydration. Applied at high rates (120 to 300 lb/1,000 bu of grain) in early studies, diatomaceous earth was shown to be a fairly effective protectant against several stored-grain insects. Labels for a new diatomaceous earth product, Insecto, recommend application of 28 to 56 lb/1,000 bu of grain. Extensive field data supporting the long-term effectiveness of rates in this range are lacking. For long-term protection, diatomaceous earth (like other protectant insecticides) must be applied at the auger as grain is binned so that it is distributed evenly throughout the grain mass within a storage. Incorporating surface treatments should provide some control of insects active in the treated layer. Labels for Insecto recommend monthly applications of 1 lb/1,000 sq ft of surface area; field data supporting the efficacy of this low rate are scant. However, applying Insecto at a rate of 28 to 56 lb/1,000 bu in the top 4 to 6 inches of grain is likely to be effective for a period of at least several weeks. Problems associated with the use of diatomaceous earth as a grain protectant throughout a grain mass include increased wear to grain-moving equipment, the generation of great amounts of airborne dust during grain handling, and possible reductions in test weight. These problems are likely to be minimal when only a topdress treatment is applied. Grain that is identified as having been treated with diatomaceous earth is no longer downgraded when inspected by official grain graders, but some buyers refuse to accept grain treated with diatomaceous earth if the appearance of the grain is altered by a dusty coating. Conversely, buyers of "organic" foods or feeds accept grains treated with diatomaceous earth or *Bacillus thuringiensis*, but not grains treated with synthetic chemical insecticides. Because of its cost and the drawbacks presented above, using Insecto to treat an entire grain mass by admixture at the auger, conveyor belt, or bucket elevator is not advised except in such unique circumstances as the long-term storage of organically certified grains. For topdress applications, diatomaceous earth is likely to give satisfactory results. Another successful and practical use of diatomaceous earth has been its addition to small seed packets to prevent infestation by stored-product pests.

Sampling Stored Grain

Stored grain should be monitored regularly to determine grain moisture content and temperature and to detect any insect infestations. Sample stored grain for insects at least monthly from November through April and at least twice monthly from May through October. Pay particular attention to the grain surface and the central core of the grain mass, but also sample additional locations and depths. Be sure to examine grain from any locations where temperature or moisture readings are substantially higher than average. Deep bin probes and sectioned grain triers are most commonly used for withdrawing samples from beneath the grain surface. Probe traps and sticky pheromone traps also are available for monitoring insects within the grain mass and flying moths, respectively. Sampling equipment is available from most bin sales and service companies.

Controlling Established Infestations

When insects are found in stored grains, a logical question is, "Are there enough insects present to warrant control?" The importance of an insect infestation is determined not only by insect numbers, but also by type of grain, insect species, time of year, grain temperature and moisture, the planned duration of storage, market potential, and local elevator quality and dockage guidelines. Revised (1988) Federal Grain Inspection Service (FGIS) standards for grain insect infestation are presented in Table 2, but local elevators usually enforce more stringent standards. Insect-damaged kernels also may result in price discounts. Consider too that insect populations and their damage can increase rapidly.

When insects are detected in stored grain, consider several possible management practices. Sometimes the most profitable action can be to clean and sell the grain immediately without any chemical treatment. Immediate sale can be especially appropriate where early stages of insect infestations are detected before insect numbers reach a buyer's detection or discount level. During cool weather, aerating to cool the grain to below 50°F can prevent insect activity and allow an extended period of safe storage.

Sometimes insect problems are limited primarily to the surface or central core of stored grain. If Indianmeal moth is the only problem, light infestations can be controlled by using *Bt*, Actellic, Reldan, or diatomaceous earth as outlined in Table 1. Unincorporated applications of these insecticides will not control Indianmeal moth larvae already present a few inches below the grain surface. Where abundant webbing indicates a severe infestation, webbing should be raked from the surface before treating; fumigation may be necessary in these situations. Where secondary beetles are confined primarily to a central core of fine material, removing one or two loads of grain to extract that core can allow safe storage of the remaining grain.

Table 2. The Number of Live Insects (per Kilogram Grain) Required for FGIS Designation as "Infested"

Crop	Insect density for designation as "infested"
Wheat, rye, triticale	• More than 1 live weevil; or
	• One live weevil plus any other live stored-grain insect or pest; or
	• No live weevils, but 2 or more other live pest insects
Corn, barley, oats, sorghum, soybeans	• More than 1 live weevil; or
	• One live weevil plus 5 or more other live soybean pest insects; or
	• No live weevils, but 10 or more live pest insects

Where infested grain can be moved to a clean bin, transfer and treatment with a protectant insecticide (see Table 1) is recommended. If possible, use a grain cleaner during the transfer process. Protectant insecticides will not immediately kill immature insects within grain kernels, but residues will eventually provide control and protect against reinfestation for a period dependent upon grain moisture and temperature. This approach is not recommended for wheat infested by the lesser grain borer.

Infested grain that cannot be treated successfully in any other way should be fumigated. The USEPA has prohibited the use of fumigants containing ethylene dibromide (EDB), ethylene dichloride (EDC), carbon bisulfide, or carbon tetrachloride. In general, chloropicrin's use directly on stored grains has also been discontinued, although carryover supplies of certain chloropicrin products labeled for application to grain can be used in such a manner.

Suspension of most liquid fumigant registrations, coupled with increased safety concerns and protective equipment requirements for remaining fumigants, tells us that fumigating farm-stored grain is potentially dangerous and difficult. Hiring a professional fumigator is recommended, especially for fumigation of bins with capacities greater than 5 to 10 thousand bushels.

Fumigation Steps

Persons not trained and certified specifically in the use of grain fumigants should not attempt to fumigate stored grain. The steps outlined below provide general guidelines, but not complete directions.

1. Level the surface of the grain, break up any caked or crusted areas, and remove any surface webbing.

2. Use tape and plastic sheeting to thoroughly seal all cracks and holes in the bin; seal the side door, unloading auger shaft, and fan openings. If the grain surface will not be tarped, also seal the eaves and roof hatches. Leave only the necessary access openings to seal after fumigant application. If the grain surface is to be tarped, tuck the plastic tarp along one edge of the structure so that it can be rolled out easily once the fumigant has been applied.

3. Spray the outside surface of the bin with malathion (4 fl oz 57% EC/gal water), chlorpyrifos-methyl (4 fl oz Reldan 4E/3 gal water), methoxychlor (1 qt 25% EC or 12 oz 50% WP/2 gal water), or cyfluthrin (8 ml Tempo 2/0.26 to 4.2 gal water/1,000 sq ft).

4. Learn and follow all safety precautions. Always work in pairs; an observer should be present *outside* the bin. The USEPA recently revised fumigant regulations. New labeling requires the use or availability of a self-contained breathing apparatus for respiratory protection during one or more stages of the fumigation process. Fumigators also must measure fumigant gas concentrations to determine that the fumigant has dissipated sufficiently before unprotected persons can enter the fumigated space. Follow specific label directions concerning respiratory protection equipment and gas detection devices. A new device that allows passive monitoring of worker exposures, the Draeger badge, also can be used to measure worker exposures to phosphine. Consult fumigant suppliers for more information on this device. Failure to follow all label instructions is unsafe and illegal. If you are uncertain about the safe use of a fumigant, contact the manufacturer for detailed recommendations.

5. Choose a calm, warm day when the grain temperature is above 60°F. Farmers and elevator operators should use only aluminum phosphide fumigants for grain fumigation.

Dry fumigants containing aluminum phosphide include Detia, Fumitoxin, Gastoxin, Phostek, and Phostoxin. Aluminum phosphide is a restricted-use fumigant. A probe should be used to place aluminum phosphide tablets or pellets in the grain mass. In farm bins, use 90 to 180 tablets or 450 to 900 pellets per 1,000 bu of bin capacity. Rates vary among different types of storage structures. Do not allow water to come in contact with tablets or pellets; wear neoprene or cotton gloves to prevent perspiration from reaching the dry material. During application, fumigant concentrations must be monitored to determine the need for respiratory protection.

6. Following application, finish tarping the grain surface or seal the access door that served as an exit from the bin. Place warning signs as directed by the fumigant label.

7. Wait at least 72 hours before airing out bins following aluminum phosphide application; follow label directions. After aeration, fumigant concentrations must be measured before warning placards can be removed and before the grain can be fed or processed.

An additional fumigant that is effective and registered for application to stored grain is methyl bromide. Safety concerns and equipment requirements limit the use of methyl bromide to application by professional fumigators.

The atmospheric gases carbon dioxide and nitrogen (alone or in combination) can be used successfully as grain fumigants. These gases are supplied for fumigation by stationary or portable generators or delivered in pressurized tanks. The fumigant gas must be introduced into a storage in a manner that displaces the original air volume; then an adequate concentration (usually around 40 to 60 percent by volume) must be maintained for a period of 4 to 10 days (longer in cool grain). For these reasons, thorough sealing is especially important. Sealing the "seams" in bolted farm bins is necessary to reduce carbon dioxide leaks. Fumigation with atmospheric gases leaves no toxic residues once the treated commodity is aerated, but it is important to remember that carbon dioxide concentrations reach toxic levels in work areas during application. Applicators and other workers must wear respiratory protection (a self-contained breathing apparatus) during periods of exposure. Fumigation using atmospheric gases is currently conducted by only a few professional fumigators and by a few large grain companies that maintain equipment at their storage sites. Where available, fumigation with carbon dioxide, nitrogen, or both can be cost-competitive and effective.

Once it is aired out, fumigated grain is subject to reinfestation. Surface application of a protectant insecticide should precede or follow fumigation if storage is to continue.

Beneficial Insects

One or more companies are marketing a program that calls for periodic releases of beneficial insects (predators and parasites of pest species) for pest management in stored grains. Although considerable research has been directed at this practice, questions concerning the ability of beneficial releases to lower pest populations to levels required by current grading standards remain unanswered. Published studies conducted in on-farm storages have not achieved adequate levels of control. Farmers and grain handlers who purchase beneficial insects for stored-grain pest management are urged to monitor results very closely.

Where management efforts must be limited to "nonchemical" methods of control, sound cultural practices (sanitation, adequate drying, cleaning, aeration, and annual rotation of the commodity) will outperform the release of beneficial insects.

Special Considerations for Stored Seeds

Seed corn in bulk storage (in cribs, bins, and granaries) can be protected from insect damage by using the storage practices and protectant insecticides discussed previously. These practices include proper sanitation, drying, cleaning, and temperature management (aeration) and the use of protectant insecticides such as pirimiphos-methyl (Actellic), malathion, *Bt*, and pyrethrin plus piperonyl butoxide. Where fumigation of bulk-stored seed corn is necessary, aluminum phosphide fumigants or carbon dioxide can be used effectively without affecting seed germination. Methyl bromide and chloropicrin reduce or destroy seed germination. In bagged seed corn (usually not treated with any insecticides), several stored-grain insects maybe a problem, but the Indian meal moth is the most common. Although bulk seed treatments using Actellic or *Bt* provide residual control of Indianmeal moth larvae, such treatments must be applied before or during bagging. Small quantities of valuable seed can be protected by cool storage or by adding diatomaceous earth to seed packets. To limit the invasion of untreated, bagged seed corn, warehouses can be fogged periodically during the summer using pyrethrins plus piperonyl butoxide. Using proper warehouse sanitation methods, maintaining cool temperatures, and excluding pests (by using screens, tight-fitting doors and windows, caulking, and so forth) also are important. Bagged seed can be effectively fumigated using aluminum phosphide fumigants. Hiring a professional fumigator is advised.

For Further Information

Additional information about pest management in stored grains can be obtained from the following sources:

Picture Sheet X798.01, Stored Grain Insects and Molds. Available for $.20 from Vocational Agriculture Services, University of Illinois, 1401 South Maryland Drive, Urbana, IL 61801.

Illinois Pesticide Applicator Training Manual 39-8: Grain Facility. Available for $7 from the Office of Agricultural Entomology, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820.

Illinois Pesticide Applicator Training Manual 39-4: Seed Treatment. Available for $2 from the Office of Agricultural Entomology, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820.

Management of Grain, Bulk Commodities, and Bagged Products. Publ. E-12. Available for $8 from the Department of Entomology, Oklahoma State University, 127 Noble Research Center, Stillwater, OK 74078 (Attn: G. Cuperus).

For a list of addresses of suppliers of insect traps, other sampling equipment, and insecticide application equipment (for stored grains), write to the Office of Agricultural Entomology, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820.

9

Insect Pest Management for Livestock and Livestock Buildings

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CONTENTS

Fly Control in Livestock Buildings and Feedlots	156
Special Review of Dichlorvos	157
Fly Control for Livestock Buildings and Feedlots	158
Pest Control for Beef Cattle and Nonlactating Dairy Cattle	162
Pest Control for Lactating Dairy Cattle	169
Pest Control for Hogs	172
Pest Control for Sheep	173
Pest Control for Goats	175
Pest Control for Poultry	175
Pest Control for Horses	177

Important Updates for 1993

- *This year's update includes a list of livestock insecticides arranged according to chemical class. This information is important in planning insecticide rotations that minimize problems with insecticide-resistant pests. See Table 9.*
- *See Tables 2 and 3 for listings and comments on such new insecticidal ear tags as Cutter Blue, Patriot, Dominator, and Rotator.*
- *Although ivermectin (Ivomec) administered by injection is an effective internal and external parasiticide, it does not dependably control biting lice. Sprays, dusts, or pour-ons containing other insecticides may be necessary to eliminate biting lice.*
- *Rabon 50% wettable powder is federally registered for use in poultry facilities and as an effective residual spray for fly control in other livestock buildings. It is unavailable in Illinois because the manufacturer, Fermenta, has chosen not to register this product with the Illinois Department of Agriculture to allow its distribution and sale in this state. Other Rabon products containing the same active ingredient are listed in this publication.*

Successful pest management is an essential part of efficient and profitable livestock production. Although pest-related losses are often inconspicuous, flies, lice, mites, and ticks can cause significant reductions in meat, milk, wool, and egg production. Several livestock pests also transmit important diseases.

Effective management of livestock pests should include the use of cultural, mechanical, and biological

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

control tactics as well as the application of chemical insecticides. Insecticides should be viewed as supplements to, not replacements for, sanitation and sound cultural practices. Used properly, insecticides efficiently reduce pest populations without injuring livestock or threatening the safety of either the pesticide applicator or the ultimate consumer of animal products.

This chapter provides recommendations for safe and effective use of livestock insecticides. It is revised annually; always use the current year's *Handbook.* Registration changes that occur between revisions will be announced to appropriate media sources and Extension offices. If you have questions about insecticides for livestock insect management, or if listed insecticides fail to provide pest control, please contact your local Extension office.

Additional Sources of Information

In the tables, leaflets outlining the life history, biology, and habits of livestock pests are indicated by the letters "NHE" and the leaflet number. Request these leaflets at your local Extension office or from Entomology Extension, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, IL 61820. Additional pest management information is presented in Circular 925, *Insect Pests of Cattle,* available from the Office of Agricultural Communications and Education, 69 Mumford Hall, 1301 West Gregory Drive, Urbana, IL 61801.

Using Livestock Insecticides

The pesticide user is always reponsible for the results of insecticide applications to the user's livestock and crops, as well as for problems of pesticide drift and contamination. All users should observe the following rules.

- Read the label and follow directions and safety precautions. Be sure that the insecticide is specifically labeled for the pest and animal in question and the application method planned. *THE LABEL IS THE LAW.*
- Use face masks or respirators and protective clothing during spraying. Avoid breathing spray mist or dust.
- If pesticides are spilled on the skin or clothing, wash thoroughly with soap and water and change clothes.
- Do not eat, drink, or smoke when handling pesticides.
- Provide adequate ventilation when applying pesticides.
- Do not exceed registered rates of application. Improper or excessive applications can endanger livestock and result in illegal residues in meat and milk.
- Obey the preslaughter interval on the label.
- Avoid drift to adjacent cropland, yards, woodlots, lakes, or ponds. Some materials may injure or kill fish, wildlife, and crops.
- Do not treat animals that are sick, over-heated, or stressed from shipping, dehorning, castration, recent weaning, and other causes.
- Avoid contamination of feed, mangers, water, milk, and milking equipment.
- Do not spread treated manure on crops that are not listed on the pesticide label.
- Accurately record all pesticide usage. Include the pesticide's trade name, formulation, dilution, application rate, and date of treatment.
- Store pesticides in their original, labeled containers, safely locked away from children, pets, and livestock.
- Dispose of empty pesticide containers promptly and properly according to specified recommendations. Do not breathe smoke from burning containers.
- Contact a physician at once in all cases of suspected poisoning. Symptoms of organophosphate poisoning include blurred vision, abdominal cramps, and tightness in the chest.

Preventing Livestock Poisoning

Every year livestock animals die after consuming pesticide granules, wettable powders, or dusts that have been spilled on trucks, wagons, or soil surfaces. Animals consume the pesticide alone or with feed grains or forage placed on the contaminated surface. Prevent livestock poisoning by properly containing and disposing of spilled pesticides and by storing all pesticides in locked facilities that are inaccessible to domestic and wild animals, as well as to children.

Fly Control in Livestock Buildings and Feedlots

Filth fly species that commonly inhabit livestock dwellings, feedlots, and nearby buildings include the house fly, stable fly, little house fly, and several blow fly species. These flies develop in a variety of moist, organic wastes including manure, spilled feed, decaying vegetation, and garbage. Common breeding sites are around feed bunks, at the edges of feeding floors, under fences, along stacks of hay or straw, in accumulations of manure, and in waste drainage areas.

Although stable flies are biting flies that take blood meals from cattle, horses, and hogs, most other flies associated with confined livestock are nuisance pests, not blood feeders. Neither stable flies nor nonbiting nuisance flies spend much time on their animal hosts, so successful fly control around confined livestock does not center on animal treatments. The use of dust bags, oilers, or ear tags provides little or no control of flies in or around buildings. Sprays directed to the legs and bellies of cattle, horses, and hogs (apply as recommended in Tables 2 through 8 for horn fly control on individual livestock species) may provide short-term relief from stable fly attack, but such applications are not likely to significantly reduce the overall fly problem.

Thorough sanitation is especially important for the control of flies around livestock buildings and feedlots. Scraping lots, removing bedding from stalls, and removing manure from under fences and feed bunks at 7- to 10-day intervals prevents fly development. Where feasible, spreading manure immediately (onset-aside acreage, for example) averts problems with continued development of flies in manure piles. Another effective way to handle animal wastes is to pile manure near the feedlot and keep it covered with a black plastic tarp. Applying an insecticide to the borders of the pile and covering the edges of the tarp with dirt prevent flies from entering or leaving the pile. Fly development can also be retarded by using sawdust instead of other materials for animal bedding.

Sanitation also includes removal of other development sites. Because grain, hay, and silage spilled outside bunks or feeders provide breeding sites for stable flies, frequent removal of wasted feed is recommended. Where large round hay bales are kept outside, thousands of stable fly larvae develop in the wet, rotting portion of each bale that touches the ground. Storing hay in sheds or under tarps reduces stable fly breeding. Keeping water tanks and hydrants leak-free and grading or filling lots to improve drainage also discourage fly breeding.

Insecticide applications may be necessary in addition to good sanitation. Unless otherwise indicated, premise treatments listed in Table 1 can be used in beef, dairy (other than milking rooms), swine, sheep, goat, poultry, and horse facilities. Separate recommendations for fly control in milking rooms are provided.

Dichlorvos

Many insecticide products containing dichlorvos (DDVP) are registered and commonly used to control pests of livestock. Among such products are Ravap (dichlorvos plus stirofos), resin strips known as "No-Pest Strips" and "Farm Strips," Vapona (liquid concentrates and dry bait), and dichlorvos horse wormers.

The United States Environmental Protection Agency (USEPA) recently completed the major portions of a Special Review of dichlorvos. This review was initiated because studies commissioned by the National Toxicology Program indicated that dichlorvos caused cancer in laboratory animals. The USEPA review panel concluded that dichlorvos is a possible human carcinogen (a downgrading from the 1988 designation of probable human carcinogen) but did not impose restrictions or other changes on dichlorvos labels.

Although registered uses of dichlorvos were deleted from the 1989 and 1990 editions of this chapter (Circular 898) pending results of the USEPA Special Review, dichlorvos is included in this year's listings. This inclusion does not imply any judgment on the issue of carcinogenicity; instead, it reflects the fact that numerous products containing dichlorvos are and will continue to be available for use in livestock pest control. This publication informs users about the specific applications of dichlorvos that are legal and effective.

Table 1. Fly Control for Livestock Buildings and Feedlots

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
House flies, stable flies, blow flies, etc.	Space spray from mist blower or fogger	To minimize control failures caused by insecticide resistance, do not apply a single insecticide repeatedly throughout an entire season. Alternate applications of pyrethroids (permethrin products) and organophosphates (naled and dichlorvos). Space sprays (aerosols) provide rapid control of adult flies present at the time of application. Close doors and windows to reduce air movement during treatment. Daily to twice-weekly applications may be necessary where space sprays are the only treatments used. Animals may be present during application, but space sprays should not be applied directly to livestock. Do not apply space sprays in areas where animals have been treated directly with an insecticide during the previous 24 hours. Do not contaminate feed or water or use in milking rooms.		
		Dibrom 8E (58% EC) or 1% Ready-to-use Spray (naled)	1 pt 8E/20 gal water. Use 5 gal dilute spray per acre of lot. Apply in mist blower or fogger.	0 days.
		Ectiban, Hard Hitter, or Insectaban 5.7% EC (permethrin)	*Misting:* Use 4 fl oz/1,000 cu ft. *Overhead system:* 1 qt/12.5 gal fuel or mineral oil; use 4 fl oz/1,000 cu ft.	0 days.
		Permectrin II 10% or Atroban 11% EC (permethrin)	*Misting:* Use 4 fl oz/1,000 sq ft. *Overhead system:* 1 qt/25 gal fuel or mineral oil; use 4 fl oz/1,000 cu ft.	0 days.
		pyrethrins plus synergist	Follow label directions.	0 days.
		Vapona 23.4% EC (dichlorvos)	*Misting:* 1 pt/6 gal water; use 1 qt/8,000 cu ft. *Fogging:* 1 pt/3.5 gal diesel oil; use 1 pt/8,000 cu ft.	0 days.
		Vapona Feedlot 43.2% EC (dichlorvos)	1 gal/100 gal water. Use 5 gal/acre.	0 days. For cattle feedlots only.
	Surface residual spray	To minimize control failures caused by insecticide resistance, do not apply a single insecticide repeatedly throughout an entire season. Alternate applications of pyrethroids (permethrin, fenvalerate) and organophosphates (diazinon, stirofos/dichlorvos). Surface sprays applied to walls, ceilings, partitions, posts, etc. kill flies at their resting sites and provide residual activity for 1 to 7 weeks. Products (or the listed concentrations of these products) recommended for use as residual sprays should not be applied directly to animals. Thoroughly spray surfaces to the point of runoff. Do not contaminate feed or water, and do not use residual sprays in milking rooms.		

Table 1. Fly Control for Livestock Buildings and Feedlots (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
House flies, stable flies, blow flies, etc., cont.	Surface residual spray, cont.	Ectiban 25% WP or 5.7% EC (permethrin) (Atroban, Hard Hitter, Insectaban, Insectrin, Expar, Overtime, Permaban, and Permectrin II are other permethrin products registered for use as surface residual sprays.)	6 oz 25% WP/11 gal water or 1 qt 5.7% EC/12.5 gal water. Use 1 gal/750 sq ft.	0 days. Some residual activity persists 3 to 7 weeks.
		(Pounce is another permethrin product that can be used as a residual spray. It is classified for restricted use; do not apply Pounce directly to poultry or livestock.)		
		Ectrin 10% WDL (fenvalerate)	1 qt/10 gal water. Use 1 gal/750 sq ft.	0 days for swine buildings. Use only in swine buildings and in horse barns where horses are not to be slaughtered. Some residual activity persists 3 to 7 weeks.
		Tempo 24.3% EC (cyfluthrin)	8 ml/1,000 sq ft. Dilution varies according to type of surface; see label.	0 days. Do not spray to dripping or runoff; see label. Remove animals before spraying. Keep them out until spray has dried.
		diazinon 50% WP	2 lb/25 gal water. Use 1 gal/350 to 750 sq ft.	0 days. Remove animals before spraying. Keep them out for at least 4 hours. Some residual activity persists 2 to 4 weeks.
		Ravap 28.7% EC (stirofos plus dichlorvos)	1 qt/6 gal water. Use 1 gal/500 to 1,000 sq ft.	0 days. Some residual activity persists 2 to 4 weeks.
	Bait	Baits may enhance house fly control; they do not attract stable flies. Bait applications of insecticides used in surface residual sprays can be prepared by adding sugar or corn syrup to the spray tank mixture. Follow directions on individual product labels. Dry baits can be sprinkled in areas where flies congregate. Do not place dry baits in areas where birds or animals will contact the bait. Do not contaminate feed or water.		
		Dipterex 1% Dry Bait (trichlorfon)	4 oz/1,000 sq ft.	0 days.
		Apache, Golden Malrin, Fly Bait Plus, or Tailspin 1% Dry Bait (methomyl)	4 oz/1,000 sq ft.	0 days.
	Manure spray	Manure sprays control fly larvae that are developing in treated feces. Migration of adult flies from nearby areas can occur if any breeding sites remain untreated. Manure sprays are recommended only where manure cannot be removed on a weekly basis. Apply sprays at rates that wet the manure surface; soaking is not necessary. Repeat applications as necessary, but not more often than every 7 days. Do not apply where mammals or birds will come in contact with the manure. Do not apply treated manure to crops not listed on the insecticide label.		
		Larvadex 5% SC (cyromazine)	1 qt/25 gal water. Use 1 gal/100 sq ft manure, pit, or lagoon surface.	0 days.
		Ravap 28.7% EC (stirofos plus dichlorvos)	1 gal/25 gal water. Use 1 gal/100 sq ft manure.	0 days.
		Vapona 23.4% EC (dichlorvos)	1 gal/25 gal water. Use 1 to 2 qt/100 sq ft manure.	0 days.

Table 1. Fly Control for Livestock Buildings and Feedlots (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
House flies, stable flies, blow flies, etc., cont.	Feed additive	Feed additives used to prevent the development of fly larvae in feces provide minimal control of flies in livestock buildings. Feed additives do not reach house fly and stable fly larvae that develop in sites other than fresh manure. Good sanitation more effectively prohibits larval development. Animals must consistently consume recommended dosages for feed additives to be effective against fly larvae in manure.		
		Larvadex 0.3% Premix (cyromazine)	1 lb/ton of feed. Mix thoroughly.	Poultry only. Feed to laying hens only; not for broilers or poultry producing eggs for hatching purposes. Continuous use of cyromazine has led to fly resistance in research trials.
		Moorman's 0.02% IGR (methoprene)	0.25 to 0.5 lb/100 lb body weight/animal/month.	0 days. Feed mineral mix or block from May through September. Beef cattle and dairy cattle only.
		Rabon 7.76% or 97.3% Oral Larvacide (stirofos)	70 mg a.i./100 lb body weight/day.	0 days. Use from May through September. Mix with complete feeds, concentrates, or protein supplements. For beef cattle, dairy cattle, or hogs only.
	Biological agents	Several companies sell parasitic wasps for use in controlling flies around livestock buildings and feedlots. These parasitic wasps attack only flies; they do not sting (or bite) other insects, animals, or humans. Adult wasps (less than 1/10 inch long) deposit eggs on or inside fly larvae or pupae. Developing wasps kill the immature flies. Suppliers usually recommend wasp releases (several thousand wasps per release) before and during the fly season. Most biological control programs recommend periodic (but not complete) removal of manure, effective water management, and control of weeds around feedlots and buildings. Some suppliers also recommend certain insecticide applications to supplement the control provided by biological agents. In many instances it is difficult to assess the separate impacts of parasitic wasps, sanitation practices, and insecticide applications. Although wasp releases have been shown to be effective for fly control in certain poultry housing, research data do not support other uses of currently available biological controls for flies. If biological control agents are to significantly contribute to fly control programs, integration with sanitation and chemical control practices is essential. Although any use of parasitic wasps must be considered experimental, existing data indicate that in the Midwest, *Spalangia nigroaenea* is the commercially available species most likely to parasitize house fly and stable fly pupae in feedlots. *Muscidifurax raptor* and *Muscidifurax zaraptor* will contribute to house fly parasitism; *Spalangia nigra, Spalangia cameroni,* and *Spalangia endius* will contribute to stable fly parasitism. Producers should not buy a blend of unspecified parasitoids or shipments that contain *Nasonia vitripennis,* a species shown to be ineffective in Midwest feedlots.		
	Diatomaceous earth	The insecticidal activity of a range of chemically inert dusts, including diatomaceous earth, results from their abrasiveness or their sorptive characteristics or both. To understand how these dusts kill insects, it is important to recognize that an insect's body covering, the cuticle, contains fat layers that make the cuticle nearly waterproof and prevent water loss. Sorptive dusts absorb fats, disrupting the cuticle's waterproof nature. Abrasive dusts damage the insect's water barrier by actually scratching or cutting the cuticle. Where inert dusts are effective as insecticides, dehydration usually causes the insect's death. For animal ectoparasite control, dusts which are sorptive or abrasive or both have been used somewhat successfully for reducing populations of lice, fleas, and some mites on a range of animal species and humans. Although most trials have evaluated silica aerogels, diatomaceous earth was used effectively to control cattle-biting lice in a study conducted in the 1930s. Silica aerogels were used at a rate of 1 to 2 ounces of dust per cow; diatomaceous earth was applied at a rate of 3 ounces per cow. Based on available evidence, it is likely that although diatomaceous earth will not work as well as currently available chemical insecticides, if applied thoroughly and repeatedly, it should provide some control of lice, fleas, and certain mites. Because of the skin-burrowing habits of swine mange mites, producers should not expect diatomaceous earth to control this pest. Like all other pesticides, insecticides containing diatomaceous earth may be used only according to USEPA-approved label directions. Advertisements claim that diatomaceous earth used as a feed additive will provide control of internal parasites and also control fly larvae in animal manure. Sales materials also include claims of controlling adult flies by aerosol, dust bag, or hand-dusting applications of diatomaceous earth to barns and animals. No reliable data support these claims of fly control.		

Table 1. Fly Control for Livestock Buildings and Feedlots (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Control of flies in milking rooms	Although effective fly control is essential in dairy barns and milkrooms, small amounts of pesticides can be detected in milk, and their presence is often illegal. To control flies and avoid residue problems, the following steps are recommended: 1. Use good sanitation and recommended insecticides in dairy barns to reduce the number of flies entering the milkroom. 2. Use sticky fly strips where appropriate. 3. Use tight screens (14 to 16 mesh) on milkroom doors and windows. Copper, aluminum, bronze, plastic, or rust-resisting screens are best. 4. Use a mist or aerosol spray of 0.06 to 0.1% pyrethrin plus piperonyl butoxide oil-based fly sprays in the milkroom when other methods do not give adequate fly control. To prevent milk contamination, cover all milking utensils, cans, bulk tanks, and containers before spraying.			
Rattailed maggots	The rattailed maggot is the larval stage of a syrphid fly. The 1¼-inch-long maggot has a cylindrical body about ¾ inch long and a tail-like breathing tube that extends ½ inch from the posterior of the body. The adult fly is a beelike hover fly that is not a pest on or around livestock or humans. Rattailed maggots live in highly polluted water such as that in livestock lagoons and manure pits. When larvae are ready to pupate, they migrate from lagoons and pits to adjacent, drier areas. They become pests when they enter feed, egg cartons, and milking rooms. To limit rattailed maggot development, eliminate floating solids within pits and keep pit sidewalls clean. Agitate the pit contents or pump the pit weekly. Although insecticides are of limited value in managing rattailed maggots, application of Ravap or Larvadex to the pit surface provides some control. Use 1 pint Ravap 28.7% EC per 3½ gallons fuel oil and apply 1 gallon of the spray mixture per 100 square feet of pit surface. (Do not agitate the pit contents after application.) Repeat applications as needed, but not more often than every 7 days. Use 1 quart Larvadex 5% SC per 25 gallons water and apply ½ to 1 gallon of finished spray per 100 square feet of pit surface. Limit rattailed maggot migration by constructing a soil barrier between the pit and the milking room. Migrating larvae will burrow into the loose soil to pupate instead of continuing their migration into milking rooms and other areas.			

Table 2. Pest Control for Beef Cattle and Nonlactating Dairy Cattle

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Lice (NHE 18) $\frac{1}{16}$ to $\frac{1}{8}$ inch long. Biting lice are reddish, flattened, and active. Sucking lice are gray to blue and sluggish. Heavy populations cause poor growth, general unthriftiness, and anemia. Symptoms are rough, patchy hair coats and a dirty appearance. Lice are most troublesome during winter months.	Self-treatment devices such as back rubbers, face rubbers, and dust bags effectively control lice when used in conjunction with systemic insecticides applied from August through October for grub control. The systemics kill lice that are present on animals during the fall; the self-treating devices then hold louse populations below economic levels throughout the winter. Place rubbing devices and dust bags where cattle will use them. For back rubbers and face rubbers, mix insecticides with No. 2 fuel oil, No. 2 diesel fuel, or an oil recommended on the insecticide label. Mineral oil is less irritating than fuel oil. Do not use waste oil or motor oil. Keep dust bags dry. Service self-treating devices at least once per month.			
	Back rubber or face rubber (oilers)	Co-Ral 11.6% EC (coumaphos)	1 gal/13 gal fuel or mineral oil.	0 days. Do not apply with oral drenches, with other internal medications such as phenothiazine, or with natural or synthetic pyrethroids, synergists, or organophosphates.
		malathion 57% EC	0.5 pt/1.5 gal fuel or mineral oil.	0 days.
	Dust bag	Products listed for use in dust bags can also be applied by hand-dusting. Follow label directions.		
		Co-Ral 1% D (coumaphos)	10 lb dust/bag. Use 1 bag/10 to 20 head.	0 days.
		Ectiban or Permectrin 0.25% D (permethrin)	10 lb dust/bag. Use 1 bag/10 to 20 head.	0 days.
		Rabon 3% D (stirofos)	4 to 8 lb dust/bag. Use 1 bag/10 to 20 head.	0 days.
	Spray	Apply sufficient spray to thoroughly wet each animal. Use up to 1 gallon finished spray per animal. Do not contaminate feed or water.		
		Co-Ral 11.6% EC or 25% WP (coumaphos)	2 qt 11.6% EC or 2 lb 25% WP/100 gal water.	0 days. Do not apply within 14 days of freshening of dairy cattle. Do not treat calves less than 3 months old or sick, convalescent, or stressed cattle. Do not spray within 10 days after shipping, weaning, or disease exposure. Do not spray in nonventilated areas. Do not apply in conjunction with other organophosphates, pyrethroids, synergists, or phenothiazine.
		Delnav 15% EC or 30% EC (dioxathion)	1 qt 15% EC or 1 pt 30% EC/25 gal water.	0 days. Do not treat more often than every 14 days. Do not use on dairy cattle or in dairy barns. Restricted-use.
		Ectiban 5.7% EC (permethrin)	1 qt/100 gal water.	0 days. Repeat treatment 14 to 21 days after first application. Do not treat more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, DeLice, Expar, Hard Hitter, Insectaban, Insectrin, Permaban, and Permectrin II are registered for control of lice on beef cattle. Check product labels for dilution and application rates.)		
		malathion 57% EC	1 gal/100 gal water.	0 days. Do not apply to lactating dairy cattle or within 14 days of freshening. Do not treat calves less than 1 month old.
		methoxychlor 25% EC or 50% WP	2 qt 25% EC or 2 lb 50% WP/25 gal water.	0 days. Repeat treatment 14 to 21 days after first application. Do not use on dairy cattle or in dairy barns.
		Ravap 28.7% EC (stirofos plus dichlorvos	1 gal/75 gal water.	0 days. Do not treat more often than once every 10 days.
		Taktic 12.5% EC (amitraz)	1 qt/100 gal water. Use up to 2 gal spray per fully grown animal.	0 days. Apply spray within 6 hours after mixing. Repeat application in 10 to 14 days.

Table 2. Pest Control for Beef Cattle and Nonlactating Dairy Cattle (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Lice, cont.	Pour-on or spot-on	Fall applications of systemic pour-ons and spot-ons such as Co-Ral (coumaphos), Ivomec (ivermectin), Warbex (famphur), Tiguvon (fenthion), Neguvon (trichlorfon), and Prolate (phosmet), or fall injections of Ivomec (ivermectia) for grub control also reduce populations of sucking lice; some of these products control biting lice. These treatments may not provide season-long louse control through the winter. Follow label directions concerning reuse after grub treatment cutoff dates. Products listed below effectively control lice but do not provide grub control.		
		Dursban 44 (chlorpyrifos)	2 cc/100 lb body weight.	14 days. Beef cattle only. Apply as spot treatment. Do not exeed 16 cc/animal. Do not treat calves under 3 months old or bulls over 8 months old. Do not treat purebred continental or exotic breed cattle such as Charolais, Chianina, Simmental, and Gelbveih. Do not re-treat within 30 days. Do not use on cows within 21 days prior to calving or 14 days after calving.
		Lysoff 7.6% EC (fenthion)	1 pt/1 gal water. Use 1 fl oz/100 lb body weight.	21 days; 35 days if 2 applications are made. Do not apply within 28 days of freshening of dairy cattle. Pour evenly along back line. Do not treat calves under 3 months old or sick, convalescent, or stressed livestock. Do not use with other cholinesterase-inhibiting insecticides or drugs.
		Atroban, DeLice, or Expar 1% (permethrin)	0.5 fl oz/100 lb body weight. Do not exceed 5 fl oz/animal.	0 days.
Cattle grubs Larvae ("grubs") bore through the skin and migrate within the host to the skin of the back. Light infestations cause little or no reduction in the rate of gain or in feed efficiency. Hide damage can be economically important if cattle are slaughtered during the spring or early summer following grub emergence. The hairy, yellow and black adult flies, slightly smaller than honey bees, annoy grazing cattle.	Most insecticides registered for use against grubs provide short-term control of lice. However, biting louse infestations have been observed on Illinois cattle despite their injection with ivermectin (Ivomec) according to label directions. Timing of grub control treatments is important. Systemic insecticides applied as pour-ons, spot-ons, or sprays travel within the animal's bloodstream and should be applied to control grubs 6 to 8 weeks before they migrate to the animal's back. Late treatments may cause host-parasite reactions with symptoms of bloat, hindquarter paralysis, or death. Systemic insecticides should be used on native beef cattle herds in August or September in southern Illinois, and in September or October in the northern half of the state. For native cattle, treat only summer-pastured cattle in areas with histories of grub problems. Cattle more than 3 years old rarely are economically infested. Animals in confinement are not attacked by ox warble flies (heel flies). Heel fly season and grub treatment dates are earlier for cattle grazed in southern states. Cattle feeders should either know the origin of feeder cattle to determine grub treatment dates or should purchase only cattle that have received grub treatments. Do not apply systemic insecticides in conjunction with or immediately after phenothiazine, with pyrethrins or synthetic pyrethroids or their synergists, or with other organophosphate insecticides. Do not treat cattle under stress from castration, dehorning, weaning, shipping, illness, or overexertion. Do not treat calves less than 3 months old.			
	Pour-on	Apply pour-ons using a long-handled dipper supplied by the manufacturer. Apply to the back line from the shoulder to the hip.		
		Co-Ral 4% (coumaphos)	Ready to use. Apply 0.5 fl oz/100 lb body weight.	0 days. Do not apply within 14 days of freshening of dairy cattle.
		Neguvon 8% (trichlorfon)	Ready to use. Apply 0.5 fl oz/100 lb body weight. Do not exceed 4 fl oz/animal.	21 days. Do not apply within 7 days of freshening of dairy cattle.
		Prolate (GX-118) 11.6% E (phosmet)	1 gal/2 gal water. Apply 1 fl oz/100 lb body weight. Do not exceed 8 fl oz/animal.	21 days. Do not apply to dairy animals.
		Tiguvon 3% (fenthion)	Ready to use. Apply 0.5 fl oz/100 lb body weight.	35 days. Do not apply within 28 days of freshening of dairy cattle.

Table 2. Pest Control for Beef Cattle and Nonlactating Dairy Cattle (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Cattle grubs, cont.	Pour-on, cont.	Warbex 13.2% (famphur)	Ready to use. Apply 0.5 fl oz/100 lb body weight. Do not exceed 4 fl oz/animal.	35 days. Do not apply within 21 days of freshening of dairy cattle. Do not use on Brahmans or Brahman cross-breeds.
		Ivomec 0.5% (ivermectin)	Ready to use. Apply 5 ml/110 body weight.	48 days. Do not treat dairy cattle of breeding age.
	Spot-on	To apply spot-ons, use the applicator system provided by the manufacturer. Apply the material to a single location on the back midline.		
		Spotton 20% (fenthion)	Ready to use. Apply 4 cc/300 lb body weight. Do not exceed 20 cc/animal.	45 days. Do not treat dairy cattle of breeding age.
	Spray	Use high-pressure sprays (250 to 350 psi) to apply 3 to 4 quarts of finished spray per animal. Because few farm sprayers generate sufficient pressure for proper application, veterinarians and commercial applicators with appropriate livestock spray equipment should be contacted to apply grub sprays. Use a pencil stream of spray directed at right angles to the sides and back. Treat 10 or fewer animals at one time. Do not contaminate feed or water.		
		Co-Ral 25% WP or 11.6% EC (coumaphos)	12 to 16 lb 25% WP or 8 to 12 qt 11.6% EC/100 gal water.	0 days. Do not apply within 14 days of freshening of dairy cattle.
		Prolate (GX-118) 11.6% EC (phosmet)	2 gal/100 gal water.	21 days. Beef cattle only.
	Injection	Ivomec 1% (ivermectin)	Ready to use. 1 ml/110 lb body weight.	35 days. Inject subcutaneously. Use aseptic procedures. Do not use on dairy cattle of breeding age.
Mange mites Microscopic mites live on the skin or burrow into it. Lesions vary with mite species. Infestations are greatest when cattle are crowded in shelters during winter months.	Chorioptic mange is the most prevalent mite-induced disorder of Illinois cattle. Infested cattle may or may not develop lesions; lesions usually occur as localized nodules that exude serum. They are most numerous from the tailhead to the hind heels. Insecticides listed previously for louse control on beef cattle also control chorioptic mange mites. Cattle scabies (psoroptic mange) is a quarantinable disease. Its symptoms are lesions that occur first on the withers, over the back, and at the tailhead. Small wounds cause itching, and rubbing leads to abscesses, especially on the shoulders and rump. Mites move to edges of scabs, causing lesions to enlarge and coalesce. Scabs may cover much of the body. Accurate diagnosis requires microscopic examination of skin scrapings. Where cattle scabies is detected, contact the Illinois Department of Agriculture, Bureau of Animal Health, Illinois State Fairgrounds, Springfield, Illinois 62706, (217)782-4944.			
Ticks Eight-legged adults of most species are reddish brown and less than ¼ inch long. Engorged females may exceed ½ inch in length. Ticks are blood feeders and disease vectors.	Ticks rarely pose an economic threat to cattle in Illinois. Problems are most likely where cattle graze in brushy or wooded areas.			
	Spray	Apply sufficient spray to thoroughly wet each animal; use up to 1 gallon finished spray per animal. Do not contaminate feed or water.		
		Co-Ral 25% WP or 11.6% EC (coumaphos)	4 lb 25% WP or 1 gal 11.6% EC/100 gal water.	0 days. Do not apply within 14 days of freshening of dairy cattle. Do not treat calves less than 3 months old or sick, convalescent, or stressed cattle. Do not spray within 10 days after shipping, weaning, or disease exposure. Do not spray in nonventilated areas. Do not apply in conjunction with phenothiazine, pyrethroids, synergists, or systemic organophosphate insecticides.
		Ectiban 5.7% EC (permethrin)	1 qt/100 gal water.	0 days. Do not apply more than once every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Hard Hitter, Insectaban, Insectrin, Permaban, and Permectrin II are registered for control of ticks on cattle. Check product labels for dilution and application rates.)		
		malathion 57% EC	1 to 2 gal/100 gal water.	0 days. Do not apply to dairy cattle within 14 days of freshening. Do not treat calves less than 1 month old.

Table 2. Pest Control for Beef Cattle and Nonlactating Dairy Cattle (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Ticks, cont.	Spray, cont.	Taktic 12.5% EC (amitraz)	1 qt/100 gal water. Use up to 2 gal spray per fully grown animal.	0 days. Apply spray within 6 hours after mixing. Repeat application in 10 to 14 days.
Mosquitoes	Mosquito populations are greatest near low, wet areas, ponds, or slow-moving streams. Reduction of mosquito breeding sites is necessary for long-term control. For information on source reduction and area treatments for mosquito control, see *Mosquitoes in Illinois: Recommendations for Prevention and Control,* an annually revised publication available from the Illinois Department of Public Health in Springfield. The insecticides listed below provide some short-term relief for treated animals, but frequent applications are not economical or recommended.			
Annoyance may cause cattle to bunch in or near buildings and reduce their grazing. High populations may cause reductions in rate of weight gain.	Spray (to animals)	Ectiban 5.7%	1 qt/100 gal water.	0 days. Do not apply more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Hard Hitter, Insectaban, Insectrin, Permaban, and Permectrin II are registered for the control of mosquitoes and horse flies on cattle. Check product labels for dilution and application rates.)		
		Vapona 23.4% EC (dichlorvos)	1 qt/6 gal water. Mist 1 to 2 fl oz/ animal/day.	1 day. Do not contaminate feed or water. Do not wet skin. Do not apply in conjunction with trichlorfon.
		pyrethrin (0.1%) plus synergist	Mist 1 to 2 fl oz/ animal.	0 days. Do not contaminate feed or water. Do not wet skin.
Horse flies, deer flies (NHE 60)	Adequate and practical control methods for horse flies and deer flies on pastured beef cattle are not available. Insecticide applications provide some relief but do not provide long-term control. Place cattle in barns or sheds to protect them from horse flies and deer flies.			
Large flies that feed on the back, shoulders, neck, and head. Blood feeding annoys cattle and reduces grazing and weight gain. Wounds attract other flies.	Spray	Ectiban 5.7%	1 qt/100 gal water.	0 days. Do not apply more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Hard Hitter, Insectaban, Insectrin, Permaban, and Permectrin II are registered for the control of mosquitoes and horse flies on cattle. Check product labels for dilution and application rates.)		
		pyrethrins (0.5 to 1.0%) plus synergist	0.5% oil is ready to use; apply 2 fl oz/animal three times per week. Mix 1 gal 1% EC/10 gal water; apply 1 to 2 pt/ animal every 3 days.	0 days. Apply to head, back, sides, belly, and legs. Do not contaminate feed or water.
Pasture flies (horn flies, face flies, stable flies)	**Threshold Infestations and Adequate Levels of Control:** Horn fly infestations of up to 100 to 200 flies per animal produce little or no effect on the rate of gain. In Illinois, control programs utilizing dust bags or oilers often reduce horn fly infestations to 10 to 50 flies per animal. The use of dust bags or oilers provides adequate and economical control of horn flies and usually does not favor rapid development of insecticide resistance (as do ear tags).			
Horn flies (NHE 59) are smaller than house flies but are similarly colored and marked. They have piercing mouthparts and are blood feeders. Horn flies congregate about the back, shoulders, and horns; on hot days they are mostly on the shady side of the animal or on the belly. Horn flies seldom follow animals into barns or sheds.	Available data do not support any estimates of what constitutes an economically damaging number of face flies or an acceptable level of face fly control. Although face flies annoy cattle, even heavy infestations do not cause reductions in the rate of gain. Face flies can transmit the pathogen that causes pinkeye, but pinkeye outbreaks also occur in the absence of face flies.			
	Research indicates that as few as one to five stable flies per leg can reduce cattle performance in some conditions. Nonetheless, there are no effective insecticide applications for reducing stable fly attacks on pastured cattle. Although sprays directed at animals' legs may provide temporary relief, no long-term control is accomplished.			
	Moving cattle into shelters reduces annoyance by horn flies and face flies, but it does not deter stable fly attack.			
	Back rubber or face rubber (oilers)	Mix insecticides with No. 2 fuel oil, No. 2 diesel fuel, or a label-recommended mineral oil. Mineral oils are less irritating than fuel oils. Do not use waste oil or motor oil. Service the rubbing device at least once per week. Self-treating devices are effective only if they are used regularly. Place rubbing devices in the entryways to water or mineral feeders to ensure usage. Effective horn fly control can be achieved with forced-use oilers; partial control of face flies is provided by these devices. Oilers do not control stable flies.		
		Co-Ral 11.6% EC (coumaphos)	1 gal/13 gal fuel or mineral oil.	0 days.
		Delnav 15% EC or 30% EC (dioxathion)	2 qt 15% EC or 1 qt 30% EC/5 gal fuel or mineral oil.	0 days. Beef cattle only.

Table 2. Pest Control for Beef Cattle and Nonlactating Dairy Cattle (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Pasture flies, cont. **Face flies** (NHE 106) resemble house flies but are slightly larger and darker. Only females frequently visit cattle. They feed on secretions about the eyes, nose, and mouth. **Stable flies** (NHE 61) resemble house flies but have a piercing proboscis that protrudes from the front of the head. Stable flies are blood feeders that often attack the lower portion of the front legs. Stable flies attack both pastured and feedlot cattle.	Back rubber or face rubber (oilers), cont.	Ectiban, Hard Hitter, Insectaban, or Insectrin 5.7% EC (permethrin)	1 qt/10 gal diesel oil.	0 days. Do not charge self-treating devices with permethrin if the treatment is intended to aid in delaying horn fly resistance to pyrethroids or to control resistant horn flies that are not controlled by pyrethroid ear tags.
		Permectrin II 10% EC (permethrin)	1 qt/20 gal fuel or mineral oil.	0 days. Do not charge self-treating devices with permethrin if the treatment is intended to aid in delaying horn fly resistance to pyrethroids or to control resistant horn flies that are not controlled by pyrethroid ear tags.
		Ravap 28.7% EC (stirofos plus dichlorvos)	1 qt/7 gal fuel or mineral oil.	0 days.
	Dust bag	Dust bags are effective only if they are used regularly. Place them in the entryways to water or mineral feeders to ensure use. Keep dust bags dry and well charged; service at least once per week. Forced-use dust bags that contact the animal's face provide effective horn fly control and significant reductions in face flies; dust bags do not effectively control stable flies.		
		Co-Ral 1% D (coumaphos)	10 lb/bag.	0 days.
		Ectiban, Insectrin, or Permectrin 0.25% D (permethrin)	10 lb/bag.	0 days. Do not charge self-treating devices with permethrin if the treatment is intended to aid in delaying horn fly resistance to pyrethroids or to control resistant horn flies that are not controlled by pyrethroid ear tags.
		malathion 4% plus methoxychlor 5% D	1 to 10 lb bag/10 to 15 animals.	0 days. Beef cattle only.
		Rabon 3% D (stirofos)	4 to 8 lb/bag.	0 days.
	Feed additive	Feed additives prevent the development of face fly and horn fly larvae in cattle dung. Stable flies do not develop in fresh dung and are not controlled by feed additives. Face flies and horn flies migrate considerable distances, so larval control in dung of a single herd may not substantially reduce fly populations if other herds in the area do not also receive boluses or feed additives. Animals must consume the recommended dosage for the feed additive to be effective.		
		Altosid or Moorman's IGR 0.02% (methoprene)	0.25 to 0.5 lb/100 lb body weight/animal/month.	0 days. Feed mineral mix or block from May to September.
		Rabon 7.76% Oral Larvacide (stirofos)	70 mg a.i./100 lb body weight/day.	0 days. Use from May through September. Mix with complete feeds, concentrates, or protein supplements.
	Bolus	Boluses release an active ingredient that prevents the development of face fly and horn fly larvae in treated dung. Stable flies do not develop in fresh dung and are not controlled by bolus use. Face flies and horn flies migrate considerable distances, so larval control in dung of a single herd may not substantially reduce fly populations if other herds in the area do not receive boluses or feed additives.		
		Vigilante 9.7% bolus (diflubenzuron)	1 bolus/550 to 1,100 lb body weight.	0 days. Use standard balling gun. Do not administer to animals weighing less than 300 pounds. No more than one bolus per animal. Boluses can be divided in half to achieve correct rate.
	Ear tag or ear tape	Before widespread development of resistance in the horn fly, ear tags and tapes impregnated with pyrethroid insecticides such as fenvalerate, flucythrinate, or permethrin effectively controlled horn flies and gave some control of face flies infesting pastured cattle. One tag or tape per cow effectively controlled horn flies for up to 20 weeks. However, midseason control failures resulting from horn fly resistance have occurred throughout Illinois in recent years.		

Table 2. Pest Control for Beef Cattle and Nonlactating Dairy Cattle (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Pasture flies, cont.	Ear tag or ear tape, cont.	Although Max-Con tags containing cypermethrin (a newer pyrethroid) plus Dursban (an organophosphate) plus a synergist are slightly more effective against resistant horn flies than the original pyrethroid tags, they do not consistently control resistant populations and can be expected to cause an increase in the level of pyrethroid resistance. Pyrethroid tags containing the more active compounds cyhalothrin (Saber, Saber Extra, and Excalibur tags) or cyfluthrin (Cutter Gold tags) have initially controlled pyrethroid-resistant horn flies, but trials conducted in the southeastern United States have shown that these tags also intensify resistance and then fail to provide control.		
		Because resistance has already reduced the performance of pyrethroid tags and tapes, and because continued use of any pyrethroids in such devices is likely to result in even higher levels of resistance (levels that may allow horn fly survival even when pyrethroid sprays or dusts are applied), this publication recommends that cattle producers refrain from using pyrethroid tags or use them only once in every three or four seasons. Tags and tapes that rely on pyrethroids for horn fly control include those containing cyfluthrin (Cutter Gold), cyhalothrin (Saber, Saber Extra, and Excalibur), fenvalerate (including Ectrin, Insecta-Shield, Ear Tag Plus, Starbar, and Vet Shack), permethrin (including Atroban, Apollo, Expar, Insecta-Gard, Gard Star, Deckem, Permectrin, and Ear Force), and flucythrinate (Guardian). Max-Con and Ear Force Ranger tags contain a pyrethroid and an organophosphate, but because it is the pyrethroid component that makes these tags effective, they should be considered to be very similar to other pyrethroid tags.		
		Tags containing the organophosphates diazinon (Terminator, Patriot, or OPtimizer tags) pirimiphos-methyl (Tomahawk, Dominator, or Rotator tags), or fenthion (Cutter Blue tags) effectively control horn flies (including pyrethroid-resistant horn flies), but they are somewhat less effective than pyrethroid tags for face fly control. They provide horn fly control for approximately 16 weeks. Attach tags in late May or early June after fly populations have begun to increase. Remove tags in September or October. Although organophosphate tags are currently effective against the horn fly in Illinois, resistance to diazinon has been documented in the southern plains. The management practice most likely to slow the development of horn fly resistance to the organophosphates used in ear tags is the avoidance of widespread reliance on such tags for pasture fly control. Do not use organophosphate tags repeatedly for more than two successive seasons. Where practical, use dust bags, oilers, or sprays containing insecticides other than those in ear tags; using feed additives or boluses is another (though slightly less effective) alternative.		
		diazinon 20% tag (Terminator or OPtimizer)	2 tags per animal.	0 days. Do not apply to calves less than 3 months old. Do not apply to lactating dairy cattle. Remove in fall or before slaughter.
		diazinon 20% calf tag (OPtimizer-calf)	2 tags per animal.	0 days. (This is a light-weight tag specifically for calves.) Do not apply to lactating dairy cattle. Remove in fall or before slaughter.
		diazinon 40% tag (Patriot)	1 tag per animal.	0 days. Do not apply to calves less than 3 months old or to lactating dairy cattle. Remove in fall or before slaughter.
		fenthion 20% tag (Cutter Blue)	2 tags per animal.	0 days. Apply to mature animals. Remove in fall or before slaughter. Can be used on lactating dairy cattle.
		pirimiphos-methyl 20% tag (Tomahawk, Dominator, or Rotator)	2 tags per animal.	0 days. Do not apply to lactating dairy cattle. Remove in fall or before slaughter.

Table 2. Pest Control for Beef Cattle and Nonlactating Dairy Cattle (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Pasture flies, cont.	Spray	Sprays directed to animals should not contaminate feed or water. Do not use sprays containing fenvalerate or permethrin to control resistant horn flies that are not controlled by pyrethroid ear tags.		
		Co-Ral 11.6% EC or 25% WP (coumaphos)	2 qt 11.6% EC or 2 lb 25% WP/ 100 gal water. Completely wet skin to runoff.	0 days. Do not apply to dairy cattle within 14 days of freshening.
		Delnav 15% EC or 30% EC (dioxathion)	1 qt 15% EC or 1 pt 30% EC/25 gal water.	0 days. Do not use more often than every 14 days. Do not use on dairy cattle or in dairy barns. Restricted-use.
		Ectiban 5.7% EC (permethrin)	1 qt/100 gal water. Thoroughly wet animals.	0 days. Repeat as needed, but not more often than once every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Hard Hitter, Insectaban, Insectrin, Permaban, and Permectrin II are registered for control of pasture flies on cattle. Check product labels for dilution and application rate.)		
		methoxychlor 25% EC or 50% WP	2 qt 25% EC or 2 lb 50% WP/25 gal water.	0 days. Do not use on dairy cattle or in dairy barns.
		Ravap 28.7% EC (stirofos plus dichlorvos)	1 gal/75 gal water. Use ½ to 1 gal/animal.	0 days. Repeat as needed, but not more often than once every 10 days.
	Pour-on	Ivomec 0.5% (ivermectin)	Ready to use. Apply 5 ml/100 lb body weight.	48 days. Do not use on dairy cattle of breeding age. Effective for 28 days.
	Trap	Large "walk-through" fly traps positioned at pasture gates (where animals must pass through the traps regularly) can reduce horn fly numbers by up to 70 percent. No insecticides are used in these traps. Additional information and plans for construction of these traps are available from the Office of Agricultural Entomology, University of Illinois, 172 Natural Resources Building, 607 East Peabody Drive, Champaign, Illinois 61820.		

Table 3. Pest Control for Lactating Dairy Cattle

Insecticides listed in this section are registered for use on lactating dairy cattle. Most insecticides listed for use on beef cattle can be applied to nonlactating dairy cattle if the specified interval between application and freshening is observed. Follow all label directions.

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Lice (NHE 18)	Dust bag	Place dust bags at milkroom exits. Keep bags charged and dry, and service at least once per month. (Co-Ral 1% dust and Ectiban and Permectrin 0.25% dusts can be used for direct hand-dusting; follow label directions.)		
$\frac{1}{16}$ to $\frac{1}{8}$ inch long. Biting lice are reddish, flattened, and active. Sucking lice are gray to blue and sluggish.		Co-Ral 1% D (coumaphos)	10 lb dust/bag.	0 days.
		Ectiban or Permectrin 0.25% D (permethrin)	10 lb dust/bag.	0 days.
Heavy populations cause reduced milk production and anemia. Symptoms are rough, patchy hair coats and a dirty appearance. Most troublesome in winter.	Spray	Apply sufficient spray to thoroughly wet each animal; use up to 1 gallon finished spray per animal. Do not contaminate feed, water, milk, or milking equipment.		
		Co-Ral 11.6% EC or 25% WP (coumaphos)	1 qt 11.6% EC or 1 lb 25% WP/100 gal water.	0 days. Do not treat calves less than 3 months old.
		Ectiban 5.7% EC (permethrin)	1 qt/100 gal water.	0 days. Repeat application 14 to 21 days after first treatment.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Hard Hitter, Insectaban, Insectrin, Permaban, and Permectrin II are registered for the control of lice on dairy cattle. Check product labels for dilution and application rates.)		
		Taktic 12.5% EC (amitraz)	1 qt/100 gal water. Use up to 2 gal per fully grown animal.	0 days. Apply spray within 6 hours after mixing. Repeat application in 10 to 14 days.
	Pour-on	Atroban, DeLice, or Expar 1% (permethrin)	0.5 fl oz/100 lb body weight. Do not exceed 5 fl oz/animal.	0 days.
Cattle grubs	No pesticides are currently registered for control of cattle grubs on lactating dairy cattle.			
Mange mites Microscopic mites live on or within skin. Lesions vary with mite species. Infestations are greatest when cattle are crowded in shelters during winter.	Mange caused by chorioptic mites (barn itch mites) is the most common mite-induced disorder of Illinois dairy cattle. Infested cattle may or may not develop lesions; lesions usually appear as localized nodules that exude serum. Lesions are most prevalent from the tailhead to the hind heels. Insecticides listed for louse control on dairy cattle also control chorioptic mange. Cattle scabies (psoroptic mange) is a quarantinable disease. Its symptoms are lesions that occur first at the withers, over the back, and at the tailhead. The wounds itch, and rubbing leads to abscesses, especially on the shoulders and rump. Mites move to edges of scabs, causing lesions to enlarge and coalesce. Scabs may cover much of the body. Accurate diagnosis requires microscopic examination of skin scrapings. Where cattle scabies is detected, contact the Illinois Department of Agriculture, Bureau of Animal Health, Illinois State Fairgrounds, Springfield, Illinois 62706, (217)782-4944.			
Ticks	Ticks are rarely economically important on Illinois dairy cattle. Problems are most likely where cattle graze in brushy or wooded areas.			
Eight-legged adults of most species are reddish brown and less than ¼ inch long. Engorged females may exceed ½ inch in length. Ticks are blood feeders and disease vectors.	Spray	Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1 to 2 qt/animal.	0 days. Do not apply more often than once every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Hard Hitter, Insectaban, Insectrin, Permaban, and Permectrin II are registered for the control of ticks on dairy cattle. Check product labels for dilution and application rates.		
		Taktic 12.5% EC (amitraz)	1 qt/100 gal water. Use up to 2 gal per fully grown animal.	0 days. Apply spray within 6 hours after mixing. Repeat application in 10 to 14 days.
Mosquitoes Blood feeding. Annoyance may cause cattle to remain in buildings and reduce their grazing.	Mosquito populations are greatest near low, wet areas, ponds, and slow-moving streams. Reduction of mosquito breeding sites is necessary for long-term control. For information on source reduction and area treatments for mosquito control, see *Mosquitoes in Illinois: Recommendations for Prevention and Control*, an annually revised publication available from the Illinois Department of Public Health in Springfield. The insecticides listed below provide some short-term relief for treated animals, but frequent applications are not economical or recommended.			
	Spray (to animals)	Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1 to 2 qt per animal.	0 days. Do not apply more often than every 14 days.

Table 3. Pest Control for Lactating Dairy Cattle (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Mosquitoes cont.	Spray, cont.	(Additional permethrin formulations including emulsifiable concentrates of Hard Hitter, Insectaban, Insectrin, Permaban, and Permectrin II are registered for the control of mosquitoes on dairy cattle. Check product labels for dilution and application rates.)		
		Vapona 23.4% EC (dichlorvos)	1 qt/6 gal water. Mist 1 to 2 fl oz/animal/day.	1 day. Do not wet skin. Do not contaminate feed, water, milk, or milking equipment.
		pyrethrins (0.03 to 0.10%) plus synergist (0.5 to 1.0%)	Ready to use. Mist 1 to 2 fl oz/animal.	0 days. Do not wet skin. Do not contaminate feed, water, milk, or milking equipment. Repeat as necessary.
Pasture flies (horn flies, face flies, stable flies)	**Threshold Infestations and Adequate Levels of Control:** In Illinois, control programs utilizing dust bags or oilers often reduce horn fly infestations to 10 to 50 flies per animal. The use of dust bags or oilers provides adequate and economical control of horn flies and usually does not favor rapid development of insecticide resistance (as do ear tags).			
Horn flies (NHE 59) are smaller than house flies but are similarly colored and marked. They have piercing mouthparts and are blood feeders. Horn flies congregate about the back, shoulders, and horns; on hot days they are mostly on the shady side of the animal or on the belly. Horn flies seldom follow animals into barns or sheds.	Available data do not support any estimates of what constitutes an economically damaging number of face flies or an acceptable level of face fly control. Although face flies annoy cattle, even heavy infestations do not cause reductions in milk production. Face flies can transmit the pathogen that causes pinkeye, but pinkeye outbreaks also occur in the absence of face flies.			
	Research indicates that as few as 1 to 5 stable flies per leg can reduce milk production in some conditions. Spraying cattle's legs as they exit the milkroom provides temporary relief, but no long-term control is accomplished.			
	Moving cattle into shelters reduces annoyance by horn flies and face flies, but it does not deter stable fly attack.			
	Back rubber or face rubber (oilers)	Mix insecticides with No. 2 fuel oil, No. 2 diesel fuel, or a label-recommended mineral oil. Mineral oils are less irritating than fuel oils. Do not use waste oil or motor oil. Service the oiler at least once per week. For self-treating devices to be effective, cattle must use them frequently. Place oilers in the entryways to water or mineral feeders or in the milking room exit. Well-used back rubbers or face rubbers will control horn flies and provide some face fly control. They will not control stable flies.		
		Co-Ral 11.6% EC (coumaphos)	1 gal/13 gal fuel or mineral oil.	0 days.
		Ectiban, Hard Hitter, Insectaban, or Insectrin 5.7% EC (permethrin)	1 qt/10 gal oil.	0 days. Do not charge self-treating devices with permethrin if the treatment is intended to aid in delaying horn fly resistance to pyrethroids or to control resistant horn flies that are not controlled by pyrethroid ear tags.
Face flies (NHE 106) resemble house flies but are slightly larger and darker. Only females frequently visit cattle. They feed on secretions about the eyes, nose, and mouth.		Permectrin II 10% EC (permethrin)	1 qt/20 gal fuel or mineral oil.	0 days. Do not charge self-treating devices with permethrin if the treatment is intended to aid in delaying horn fly resistance to pyrethroids or to control resistant horn flies that are not controlled by pyrethroid ear tags.
Stable flies (NHE 61) resemble house flies but have a piercing proboscis that protrudes from the front of the head. Stable flies are blood feeders that often attack the lower portion of the front legs. Stable flies attack both pastured and feedlot cattle.	Dust bag	For self-treating devices to be effective, cattle must use them regularly. Place dust bags in the entryways to water or mineral feeders or in the milking room exit. Keep dust bags dry; service at least once per week. Dust bags will control horn flies and provide some reduction in face fly problems. They will not control stable flies. (*Note:* Insecticide dusts listed below can also be used for direct hand-dusting; follow label directions.)		
		Co-Ral 1% D (coumaphos)	10 lb/dust bag.	0 days. Do not treat calves less than 3 months old.
		Ectiban, Insectrin, or Permectrin 0.25% D (permethrin)	10 lb/dust bag.	0 days. Do not charge self-treating devices with permethrin if the treatment is intended to aid in delaying horn fly resistance to pyrethroids or to control resistant horn flies that are not controlled by pyrethroid ear tags.
		Rabon 3% D (stirofos)	4 to 8 lb/dust bag.	0 days.
	Spray	It is important that the following sprays do not contaminate feed, water, milk, or milking equipment. Do not use sprays containing fenvalerate or permethrin to control resistant horn flies that are not controlled by pyrethroid ear tags.		

Table 3. Pest Control for Lactating Dairy Cattle (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
		Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1 to 2 qt/animal.	0 days. Repeat as needed, but not more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Hard Hitter, Insectaban, Insectrin, Permaban, and Permectrin II are registered for pasture fly control on dairy cattle. Check product labels for dilution and application rates.)		
		pyrethrins (0.1%) plus synergist	Ready to use. Apply 1 to 2 fl oz/animal.	0 days. Repeat as needed.
		Vapona 23.4% EC or 1% EC oil base (dichlorvos)	1 qt 23.4%/6 gal water; use 1 to 2 fl oz/animal/day. *Or:* 1% EC (oil base), ready to use; mist 1 to 2 fl oz/animal/day.	0 days. Do not wet skin.
	Feed additive	Feed additives prevent the development of face fly and horn fly larvae in cattle dung. Stable flies do not develop in fresh dung and are not controlled by feed additives. Face flies and horn flies migrate considerable distances, so larval control in the dung of a single herd may not substantially reduce fly populations if other herds in the area do not also receive boluses or feed additives. Animals must consume the recommended dosage for the feed additive to be effective.		
		Altosid or Moorman's IGR 0.02% (methoprene)	0.25 to 0.5 lb/100 lb body weight/month.	0 days. Feed mineral mix or blocks from May to September.
		Rabon 7.76% Oral Larvicide (stirofos)	70 mg a.i./100 lb body weight/day.	0 days. Feed in complete feeds, concentrates, or protein and mineral supplements from May to September.
	Bolus	Boluses release an active ingredient that prevents the development of face fly and horn fly larvae in treated dung. Stable flies do not develop in fresh dung and are not controlled by bolus use. Face flies and horn flies migrate considerable distances, so larval control in dung of a single herd may not substantially reduce fly populations if other herds in the area do not receive boluses or feed additives.		
		Vigilante 9.7% bolus (diflubenzuron)	1 bolus/550 to 1,100 lb body weight.	0 days. Use standard balling gun. Do not administer to animals weighing less than 300 pounds. No more than one bolus per animal. Boluses can be divided in half to achieve correct rate.
	Ear tag or ear tape	Before widespread development of resistance in the horn fly, ear tags and tapes impregnated with pyrethroid insecticides such as fenvalerate, flucythrinate, or permethrin effectively controlled horn flies and gave some control of face flies infesting pastured cattle. One tag or tape per cow effectively controlled horn flies for up to 20 weeks. However, midseason control failures resulting from horn fly resistance have occurred throughout Illinois in recent years. Although Max-Con tags containing cypermethrin (a newer pyrethroid) plus Dursban (an organophosphate) plus a synergist are slightly more effective against resistant horn flies than the original pyrethroid tags, they do not consistently control resistant populations and can be expected to cause an increase in the level of pyrethroid resistance. Pyrethroid tags containing the more active compounds cyhalothrin (Saber, Saber Extra, and Excalibur tags) or cyfluthrin (Cutter Gold tags) have initially controlled pyrethroid-resistant horn flies, but trials conducted in the southeastern United States have shown that these tags also intensify resistance and then fail to provide control. Saber and Excalibur tags are not registered for use on lactating dairy cattle. Because resistance has already reduced the performance of pyrethroid tags and tapes, and because continued use of any pyrethroids in such devices is likely to result in even higher levels of resistance (levels that may allow horn fly survival even when pyrethroid sprays or dusts are applied), this publication recommends that cattle producers refrain from using pyrethroid tags or use them only once in every three or four seasons. Tags and tapes that rely on pyrethroids for horn fly control include those containing cyfluthrin (Cutter Gold), fenvalerate (including Ectrin, Insecta-Shield, Ear Tag Plus, Starbar, and Vet Shack), permethrin (including Atroban, Apollo, Expar, Insecta-Gard, Gard Star, Fearing Du-flex, Permectrin, Ear Force, and Ear Force Ranger), cypermethrin (Max-Con), and flucythrinate (Guardian). Tags containing the organophosphate fenthion (Cutter Blue) are registered for use on lactating dairy cattle and should control horn flies for about 16 weeks. Use 2 tags per animal. Remove in fall or before slaughter. The organophosphates diazinon (Terminator, Patriot, and OPtimizer tags) and pirimiphos-methyl (Dominator, Rotator, and Tomahawk tags) should *not* be used on lactating dairy cattle.		

Table 4. Pest Control for Hogs

Mange mites (and lice)

Microscopic mites feed on or within skin and cause mange.

Sarcoptic mange usually starts at the head and then spreads back; infested skin becomes dry, scurfy, or leathery. Rubbing may lead to raw or scabby areas.

Demodectic mange is characterized by hard, round swellings on or below the skin surface.

Although mange mites and lice are blamed for substantial losses in swine production, controlled studies indicate that otherwise healthy pigs suffer little or no reduction in the rate of gain or feed efficiency when infested with mange mites and lice. Managing lice and mange mites remains an important step in swine production, but keeping every animal louse-free and mange-free through the time of sale and slaughter is probably *not* economically justified.

Mange mites and lice are spread by direct contact among animals. They may survive off the host animal for short periods in bedding, but they do not infest animals other than swine. Prevent mange outbreaks by isolating and treating any new animals — especially boars — before adding them to the herd. (SPF breeding stock are treated and declared free of mange and lice before sale.) Thoroughly clean and disinfect pens before using them to hold uninfested animals. To prevent infestation of newborn pigs, treat boars before the breeding season and treat sows before farrowing. It is often necessary to treat all animals in contact with those infested by mange mites or lice. It is also wise to isolate carrier animals to prevent the unnecessary spread of these pests from animal to animal.

The insecticides listed below will help to control sarcoptic mange. There is no satisfactory chemical control for the hog follicle mites that cause demodectic mange. Isolate hogs with demodectic mange. Kill and destroy severely infested animals; market for slaughter the animals that are severely attacked. Clean and disinfect pens, sheds, and other infested areas before moving in uninfested animals.

Follow label precautions against the simultaneous use of organophosphate sprays, dusts, or pour-ons with similar medications used for internal parasite control. Do not contaminate feed or water.

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Mange mites (and lice)	Spray	Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Spray animals thoroughly.	5 days. Repeat application after 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Insectaban, Insectrin, Permaban, and Permectrin II are registered for control of hog lice and mange. Check product labels for dilution and application rates.)		
		Ectrin 10% WDL (fenvalerate)	1 qt/50 gal water. Spray each animal thoroughly.	1 day. Repeat application in 14 days if necessary.
		lindane 12.4% EC or 20% EC	3 pt 12.4% EC or 1 qt 20% EC/100 gal water. Spray animals thoroughly.	30 days. Treat twice at a 7-day interval. Do not treat pigs less than 3 months old. Do not treat sows within 2 weeks before farrowing or 3 weeks after farrowing. Restricted-use.
		malathion 57% EC	1 qt/15 gal water. Treat animals, bedding, and walls thoroughly.	0 days. Do not treat pigs less than 1 month old. Repeat treatment after 10 days.
		Prolate 11.6% EC (phosmet)	2 qt/50 gal water. Treat animals thoroughly.	1 day. Do not treat pigs less than 3 months old.
		Taktic 12.5% EC (amitraz)	1 qt/50 gal water. Spray animals, bedding, and walls thoroughly.	1 day. Apply spray within 6 hours after mixing. Repeat application in 7 to 10 days.
	Dust	malathion 4 to 5% D	Thoroughly cover animals over 1 month old. Also treat pens and bedding. Use ¼ to ½ tbsp/pig for pigs less than 1 month old.	0 days. Repeat as needed. Gives only partial control of mange mites.
	Injection	Ivomec 1% (ivermectin)	1 ml/75 lb body weight.	18 days. Inject subcutaneously. Use aseptic procedures. A 0.27% formulation is also available.

Table 4. Pest Control for Hogs (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Lice Up to ⅙ inch long. Hog lice are bluish black in color. They suck blood from infested animals.	Insecticides listed for controlling mange mites on hogs will also control lice. Do not contaminate feed or water. Follow label precautions against the simultaneous use of organophosphate sprays, dusts, or pour-ons with medications used for internal parasite control.			
	Spray	Co-Ral 25% WP (coumaphos)	2 lb/100 gal water. Spray each animal thoroughly.	0 days. Do not treat animals less than 90 days old. Apply a second spray 10 to 14 days after first.
		methoxychlor 50% WP	8 lb/100 gal water. Spray each animal thoroughly.	0 days. Make second application 14 days after first if needed.
	Dust	Co-Ral 1% D (coumaphos)	1 oz/animal.	0 days. Dust especially around shoulders and back. Repeat as needed, but not more than once every 10 days.
		Ectiban, Insectrin, or Permectrin 0.25% D (permethrin)	1 oz/animal.	5 days. Make second application 14 days after first.
		Rabon 3% D (stirofos)	3 to 4 oz/animal; 1 lb/150 sq ft of bedding for severe infestations.	0 days. Do not re-treat for 14 days.
	Pour-on	Ectrin 10% WDL (fenvalerate)	1 qt/25 gal water. Pour 4 fl oz/animal on head and back midline.	1 day. Add wetting agent according to label directions. Repeat application in 14 days if necessary.
		Tiguvon 3% Pour-On (fenthion)	0.5 fl oz/100 lb body weight.	14 days. May be used on gestating and lactating sows. Do not re-treat within 35 days.

Table 5. Pest Control for Sheep

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Keds, lice (NHE 53) **Sheep keds** (also called sheep ticks) are flattened, wingless, reddish brown flies about the size of house flies. **Lice** reach $\frac{1}{16}$ to ⅛ inch in length. Biting lice are flattened and yellowish to reddish in color. Sucking lice are oval and bluish gray.	Spray	Apply enough spray to thoroughly cover each animal. Do not contaminate feed or water.		
		Co-Ral 25% WP (coumaphos)	*Lice:* 2 lb/100 gal water. *Keds:* 4 lb/100 gal water.	15 days. Do not treat lambs less than 3 months old.
		diazinon 50% WP	0.5 lb/100 gal water. Use 1 gal/animal.	14 days. Use high pressure and volume. Do not treat lambs less than 2 weeks old.
		Ectiban, Hard Hitter, or Insectaban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1 to 2 qt/animal.	0 days. Repeat application in 14 days. Do not treat more often than every 14 days.
		Ectrin 10% WDL (fenvalerate)	1 qt/100 gal water. Wet each animal with up to 1 qt of spray.	2 days. Repeat application in 30 days if necessary. Do not apply more than twice in the spring and twice in the fall.
		malathion 57% EC	1 gal/100 gal water.	0 days. Do not treat lambs less than 1 month old.
		Marlate 50% WP (methoxychlor)	8 lb/100 gal water. Spray each animal thoroughly.	0 days.
	Dip	Co-Ral 25% WP (coumaphos)	*Lice:* 2 lb/100 gal water. *Keds:* 4 lb/100 gal water.	15 days. Do not dip lambs less than 3 months old.

Table 5. Pest Control for Sheep (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Keds, lice, cont.	Dip, cont.	Del-Tox 20.4% EC (dioxathion)	2 qt/100 gal water.	0 days. Do not dip lambs less than 3 months old or sick, convalescent, or stressed animals. Prevent ingestion of dip. Dioxathion is available in additional formulations including Co-Nav, a restricted-use product.
	Dust	Co-Ral 0.5% D	Follow label directions.	15 days. Treat once after shearing. Do not treat lambs less than 3 months old.
		diazinon 2% D	1½ oz/animal.	14 days. Do not treat lambs less than 2 weeks old.
		malathion 4 to 5% D	1 to 2 oz/animal.	0 days. Repeat application in 2 to 3 weeks if needed. Do not treat lambs less than 1 month old.
		Marlate 50% WP (methoxychlor)	1 tbsp/animal.	0 days. Treat only once.
	Pour-on	Ectrin 10% WDL (fenvalerate)	2 qt/25 gal water. Pour 4 fl oz/animal down midline of back.	2 days. Add wetting agent according to label directions. Repeat application in 30 days if necessary. Do not apply more than twice in the spring and twice in the fall.
Nasal bots	Oral drench	Ivomec 0.08% solution (ivermectin)	3 ml/26 lb body weight	11 days. Administer orally.
Wool maggots Cream-colored maggots are larvae of blow flies. Maggots live in wet, matted wool near the rear of the animal and in matted wool surrounding wounds.	Spray	Reduce wool maggot attacks by tagging sheep (shearing under the tail and between the hind legs), docking, and castrating before May. Practice good sanitation. Shear around and direct sprays to the infested areas.		
		Co-Ral 25% WP (coumaphos)	4 lb/100 gal water. Use 1 gal/animal.	15 days. Do not treat lambs less than 3 months old.
Scab mites (scabies, wet mange)	Sheep scab is a quarantinable disease. Infested animals shed wool; skin becomes roughened and crusted. Where infestations are suspected, contact the Illinois Department of Agriculture, Bureau of Animal Health, Illinois State Fairgrounds, Springfield, Illinois 62706, (217)782-4944.			
Horn flies (NHE 59) **Face flies** (NHE 106)	Spray	Co-Ral 25% WP (coumaphos)	2 lb/100 gal water.	15 days. Do not treat lambs less than 3 months old.
		Ectiban, Hard Hitter, or Insectaban 5.7% EC (permethrin)	1 qt/25 gal water. Apply 1 to 2 qt/animal.	0 days. Do not treat more often than every 14 days.
		Marlate 50% WP (methoxychlor)	2 lb/100 gal water.	0 days. Repeat treatment every 3 weeks as needed.
		pyrethrins (0.05 to 0.10%) plus synergist (0.5 to 1.0%)	1 to 2 fl oz/animal.	0 days. Apply daily to head, neck, and front legs as a fine mist. Do not wet hair or skin.

Table 6. Pest Control for Goats

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Lice (NHE 53)	Spray	Ectrin 10% WDL (fenvalerate)	1 qt/100 gal water. Wet each animal with up to 1 qt of spray.	2 days. Do not apply to lactating goats. Repeat application in 30 days if necessary. Do not apply more than twice in the spring and twice in the fall.
	Pour-on	Ectrin 10% WDL (fenvalerate)	1 qt/25 gal water. Pour 4 fl oz/animal down midline of back.	2 days. Do not apply to lactating goats. Add wetting agent according to label directions. Repeat application in 30 days if necessary. Do not apply more than twice in the spring and twice in the fall.
Face flies (NHE 106), **Horn flies** (NHE 59), **Stable flies** (NHE 61), **Horse flies, deer flies** (NHE 60)	Spray	pyrethrins (0.05 to 0.10%) plus synergist (0.5 to 1.0%)	1 to 2 fl oz/animal.	0 days. Apply to head, neck, and front legs as a fine mist. Do not wet hair or skin.

Table 7. Pest Control for Poultry

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Lice, northern fowl mites (bird treatment) (NHE 54) **Chicken lice** are flat-bodied, straw-colored, 1/16-inch-long lice with chewing mouthparts. They feed on feathers and skin flakes, irritating birds. Severe infestations reduce egg production. **Northern fowl mites** are dark red to black blood feeders that build up in the vent area. Mature mites are roughly 1/25 inch long. Feathers around the vent appear grayish or black from accumulation of mites, mite eggs, and excrement. Severe infestations reduce egg production and can cause death. Northern fowl mites are most troublesome in winter.	Spray	Co-Ral 25% WP (coumaphos)	*Lice:* 6 oz/5 gal water. *Mites:* 3 oz/5 gal water. Use 1 gal/100 to 125 birds, or 0.5 fl oz/bird.	0 days. Do not treat more than once per week. Do not treat within 10 days of vaccination or stress.
		Ectiban, Hard Hitter, or Insectaban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1 gal/100 birds.	0 days. Treat vent area thoroughly.
		malathion 57% EC	1 fl oz/gal water. Use 1 gal/100 to 125 birds.	0 days. Repeat treatment in 4 to 8 weeks or when necessary.
		Permectrin II 10% EC or Atroban, Expar, or Permaban 11% EC (permethrin)	1 qt/50 gal water. Use 1 gal/100 birds.	0 days. Treat vent area thoroughly.
		Sevin 50% WP or 80% SP (carbaryl)	6 oz 50% WP or 4 oz 80% SP/5 gal water. Use 1 gal/ 100 birds.	7 days. Repeat treatment in 4 weeks if necessary.
	Dust	Ectiban or Permectrin 0.25% D (permethrin)	Use 1 lb/100 birds.	0 days. Apply with shaker or hand duster. Treat vent area thoroughly.
		malathion 4 to 5% D	Use 1 lb/100 birds.	0 days. Apply with shaker or hand duster.
		Rabon 3% D (stirofos)	Use 1 lb/300 birds.	0 days. Apply with hand or power duster. Do not treat more than once every 14 days.
		Sevin 5% D (carbaryl)	Use 1 lb/100 birds.	7 days. Apply with shaker or hand duster. Do not treat more than once every 4 weeks.
	Strip	Permectrin 10% strip (permethrin)	1 or 2 strips per cage of up to 9 hens.	0 days. For northern fowl mite control.

Table 7. Pest Control for Poultry (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Lice, chicken mites, northern fowl mites (poultry house and litter treatment) (NHE 54) **Chicken mites** (or roost mites) are bright to dark red and 1/25 inch long. They hide in cracks and crevices during the day and feed on birds at night. They are most prevalent in spring, summer, and fall, not in winter.	Spray	Co-Ral 25% WP (coumaphos)	6 oz/5 gal water. Use 1 gal/1,000 sq ft.	0 days. Apply thoroughly to litter, walls, ceilings, floors, roosts, nests, and adjacent areas. Force spray into all cracks and crevices.
		malathion 57% EC	2 fl oz/gal water. Use 1 gal/1,000 sq ft.	0 days. Apply liberally to litter, walls, ceilings, floors, roosts, nests, and adjacent areas. Force spray into cracks and crevices.
		Sevin 50% WP or 80% SP (carbaryl)	2 lb 50% WP or 1.5 lb 80% SP/5 gal water. Use 1 to 2 gal/1,000 sq ft.	7 days. Apply spray to walls, bedding, litter, and roosts. Force spray into cracks and crevices. Repeat as needed. Avoid contamination of nests, eggs, feed, and water.
	Dust	malathion 4 to 5%	1 lb/50 to 60 sq ft.	0 days. Apply liberally to litter, walls, ceilings, roosts, nests, and adjacent areas.
		Rabon 3% D	1 lb 3% D/100 sq ft.	0 days. Treat litter evenly and thoroughly.
		Sevin 5% D (carbaryl)	1 lb/40 sq ft.	7 days. Apply to litter, roosts, and adjacent areas. Do not apply to eggs or nests. Do not treat more than once every 4 weeks.
Darkling beetles (lesser mealworms) Cream-colored larvae infest decaying organic matter or moldy feeds. Can serve as intermediate hosts for poultry pathogens. Sometimes nest in and damage building insulation.	Spray	Sevin 80% SP or 40% or 43.4% suspensions (carbaryl)	62.5 lb 80% SP or 50 qt 40% or 43.4% suspensions/100 gal water. Use 2 gal/1,000 sq ft.	7 days. Apply evenly and thoroughly to litter or floor surface. Do not appy directly to poultry, nests, or eggs. Repeat as needed.
	Dust	Sevin 5% D (carbaryl)	1 lb/40 sq ft.	7 days. Do not apply to eggs or nest litter. Do not treat more than once every 4 weeks.
		(Additional dusts registered by the USEPA to control mealworms include Safecide [boric acid], Littershield [stirofos plus diatomaceous earth], and Red Zone. See product labels for application methods and rates.)		
Bed bugs Flat, reddish brown, blood-sucking insects that feed at night. Rarely seen on birds during daylight.	Spray	Sevin 50% WP, 80% SP, or 40% or 43.4% suspensions (carbaryl)	8 lb 50% WP, 5 lb 80% SP, or 4 qt 40% or 43.4% suspensions/100 gal water. Use 1 to 2 gal/1,000 sq ft.	7 days. Apply thoroughly to walls, litter, and roost surfaces. Force spray into cracks and crevices. Do not apply directly to poultry, nests, or eggs. Repeat as needed.
	Dust	Sevin 5% D (carbaryl)	1 lb/40 sq ft.	7 days. Apply evenly to litter. Do not treat more than once every 4 weeks. Do not apply to eggs or nest.

Table 8. Pest Control for Horses

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Mange mites Burrowing in skin causes pain and itching. Most prevalent in winter.	Spray	Ectiban, Hard Hitter, or Insectaban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1 to 2 qt/animal.	0 days. Repeat application in 14 days. Do not treat more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Insectrin, Permaban, and Permectrin II are registered for the control of mites on horses. Check product labels for dilution and application rates.)		
Lice $\frac{1}{16}$ to $\frac{1}{8}$ inch in length. Biting lice are yellow to red. Sucking lice are brownish to blue-gray. Head and neck, withers, and tailhead develop a scurfy appearance. Rubbing may create raw areas.	Spray	Co-Ral 25% WP or 11.6% EC (coumaphos)	0.5 lb 25% WP or 1 pt 11.6% EC/25 gal water. Treat animal thoroughly.	0 days.
		Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1 to 2 qt/animal.	0 days. Repeat application in 14 days. Do not treat more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Hard Hitter, Insectaban, Insectrin, Permaban, and Permectrin II are registered for the control of lice on horses. Check product labels for dilution and application rates.)		
		malathion 57% EC or 25% WP	6.5 to 10 fl oz 57% EC or 0.75 lb 25% WP/ 5 gal water. Treat animal thoroughly.	0 days.
Ticks Seldom a problem unless horses graze in brushy or wooded areas.	Spray	Co-Ral 25% WP or 11.6% EC (coumaphos)	1 lb 25% WP or 1 qt 11.6% EC/25 gal water. Treat animal thoroughly.	0 days. Repeat as necessary.
		Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1 to 2 qt/animal.	0 days. Do not treat more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Hard Hitter, Insectaban, Insectrin, Permaban, and Permectrin II are registered for the control of ticks on horses. Check product labels for dilution and application rates.)		
		malathion 57% EC or 25% WP	6.5 to 10 fl oz 57% EC or 0.75 lb 25% WP/ 5 gal water. Treat animal thoroughly.	0 days.
Horse bots Flies are nearly as large as honey bees. They deposit eggs on the forelegs, throat, or muzzle area; fly activity severely annoys horses. Eggs are ingested; larvae (bots) develop within the horse's alimentary canal.	Feed additive	Anthon 90% Powder (trichlorfon)	5 g/250 lb body weight mixed with feed. Treat from mid-October to mid-December.	Nonfood use. Repeat after 3 to 4 months. Withdraw all feed 12 to 18 hours prior to and 3 hours after treatment. Do not treat colts under 4 months of age, mares in the last month of gestation, or horses to be used for food.
	Oral paste	Eqvalan 1.87% (ivermectin)	Ready to use. Follow directions on prefilled tube.	Nonfood use.
		Equibot or Combot (trichlorfon)	Ready to use. Follow directions on prefilled syringe.	Nonfood use.
	Stomach tube	Consult with a veterinarian for treatment with carbon disulfide, or piperazine + carbon disulfide (Parvex Plus).		
	Preventive spray	malathion 57% EC	During fall months, sponge legs, under jaw, and chest of animal with a warm 0.5% malathion solution.	0 days. Eggs will be stimulated to hatch and the larvae will be prevented from burrowing into the animal. Retreat when more eggs accumulate. Do not use bare hands; use specially prepared gloves or rubber gloves.
Screwworms, blow flies Maggots develop in wounds.	Spray	Co-Ral 25% WP (coumaphos)	1.3 oz/gal water. Treat wound lightly but thoroughly.	0 days.
		Co-Ral 3% Spray Foam (coumaphos)	Ready to use. Spray thoroughly so that foam completely covers wound.	0 days.

Table 8. Pest Control for Horses (cont.)

Pest	Treatment method	Insecticide and formulation	Dilution and rate	Preslaughter interval, restrictions, comments
Screwworms, blow flies, cont.	Dust	Co-Ral 5% D (coumaphos)	Ready to use. Treat wound lightly but thoroughly.	0 days.
Horn flies, face flies, stable flies, horse flies, deer flies, black flies, mosquitoes	Spray	Co-Ral 25% WP or 11.6% EC (coumaphos)	0.5 lb 25% WP or 1 pt 11.6% EC/25 gal water. Treat animal thoroughly.	0 days.
		malathion 57% EC or 25% WP	6.5 to 10 fl oz 57% EC or 0.75 to 1.25 lb 25% WP/5 gal water. Treat animal thoroughly.	0 days.
		Ectiban 5.7% EC (permethrin)	1 qt/25 gal water. Use 1 to 2 qt/animal.	0 days. Do not treat more often than every 14 days.
		(Additional permethrin formulations including emulsifiable concentrates of Atroban, Expar, Hard Hitter, Insectaban, Insectrin, Permaban, and Permectrin II are registered for the control of biting flies on horses. Check product labels for dilution and application rates.)		
		Ectrin 10% WDL (fenvalerate)	4 fl oz/3 gal water. Mist 8 fl oz spray per animal. Direct at face, head, shoulders, and legs.	Do not treat animals intended for slaughter.
		pyrethrins plus synergist	Ready to use.	0 days. Apply as a mist spray. Do not wet the hide. Repeat as needed.
		Rabon 1% Spray-n-Wipe (stirofos)	Apply 1 to 2 fl oz to flanks, belly, and back.	0 days.
	Dust	Co-Ral 1% D (coumaphos)	2 oz/animal.	0 days. Apply to the head, neck, shoulders, back, and tailhead. Repeat as needed.
		malathion 4% D	4 tbsp/animal.	0 days. Apply evenly along back line. Repeat at 10- to 14-day intervals.
	Wipe-on	Rabon 2% Gel Wipe-on (stirofos)	1 to 2 fl oz/animal.	0 days. Apply as directed every 2 to 3 days if needed.

Table 9. Major Classes of Insecticides and Active Ingredients Registered for One or More Uses On or Around Livestock

Class of insecticide	Common names of active ingredients
Chlorinated hydrocarbons (organochlorines)	lindane, methoxychlor
Organophosphates	chlorpyrifos, coumaphos, diazinon, dichlorvos, dioxathion, famphur, fenthion, malathion, naled, phosmet, pirimiphos-methyl, stirofos, trichlorfon
Carbamates	carbaryl, methomyl
Pyrethroids	allethrin, cyfluthrin, cyhalothrin, cypermethrin, fenvalerate, flucythrinate, permethrin, pyrethrins, resmethrin
Formamidines	amitraz
Insect juvenile hormone analogs	methoprene
Substituted ureas	diflubenzuron
Avermectins	ivermectin
Synergists	piperonyl butoxide (PBO)
Others	cyromazine, diatomaceous earth

Vegetable Crops

10

Insect Pest Management for Commercial Vegetable Crops

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Important Updates for 1993

- *Table 1 includes estimates of action thresholds for several major pests. Although some of these estimates have not been verified by research in Illinois, they provide useful guidelines for determining whether or not control is necessary in an individual field.*

- *New registrations for 1993 include Larvin (a carbamate insecticide), as well as Xentari and Agree, two new products that contain* Bacillus thuringiensis. *Listings in the sections on cole crops and leafy greens in Table 1 include these insecticides.*

- *All uses of parathion (ethyl parathion) on fruits and vegetables were cancelled in 1991 by a voluntary agreement between manufacturers and the U.S. Environmental Protection Agency. Although parathion has not been recommended in this insecticide guide, some growers have used it on vegetables according to label directions. As of December 31, 1991, such uses are no longer legal. Existing supplies are* **not** *to be used according to old label directions. This ruling does not affect methyl parathion, commonly sold as Penncap-M.*

- *The carbamate insecticide Lannate (methomyl) and the pyrethroids Pounce and Ambush (permethrin) have been used successfully on certain cole crops (see labels and Tables 1 and 2) for the control of caterpillars. These insecticides consistently control imported cabbage worm and cabbage looper, but in some areas diamondback moth is resistant to these compounds. Control failures have been observed in Illinois. As an alternative to these insecticides, use products containing* Bacillus thuringiensis kurstaki *to kill larvae of diamondback moth; this insecticide kills only the caterpillars that eat it.*

Insect control is a major concern for commercial vegetable producers. Processors, grocers, and most consumers do not purchase insect-damaged or insect-contaminated produce. At the same time, however, processors, distributors, and consumers are concerned about pesticide residues; they want to know that the health benefits provided by eating vegetables are not offset by any possible risks posed by pesticides that remain on fresh produce. To meet simultaneous demands for maximum pest control and minimum pesticide residues, the careful selection and use of insecticides are essential steps in commercial vegetable production.

This guide to insecticides is intended for use by commercial vegetable producers, not home gardeners. Commercial producers should be trained and equipped to handle a variety of pesticides, including some that are highly toxic. Because few home gardeners are similarly trained or equipped, and because yield and cosmetic standards are not rigorous for the backyard garden, homeowners are advised to use a narrower selection of insecticides that are generally

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

less hazardous to store, mix, and apply. A guide to insecticides for yard and garden use is presented in Chapter 6 in the *1993 Illinois Urban Pest Control Handbook.*

Most of the information contained in this publication is presented in table format. Table 1 lists the registered insecticides that are most likely to control specific target pests in specific commodities in Illinois. Fact sheets on individual insects are also listed by NHE numbers in parentheses in Table 1. Contact the Office of Agricultural Entomology, 172 Natural Resources Bldg., 607 East Peabody Drive, Champaign, IL 61820, to obtain copies at a cost of 25 cents each. Information on the safety and effectiveness of individual insecticides was evaluated in order to develop these lists; not all registered and legal uses of insecticides are presented in Table 1. Table 2 provides a more complete list of insecticides registered for use on vegetables; it also summarizes mandatory preharvest intervals (the time that must elapse between final application and harvest) for applications to specific crops. Check individual product labels for additional restrictions, such as the use of crop residues (tops, trimmings, stalks, etc.) for livestock feed. Certain insecticides listed in Table 2 are not among the best choices for the control of Illinois vegetable pests, but they are registered and can be used legally. Consequently, the information in Table 2 may be useful where drift, overspray, or other contamination is a concern. Table 3 lists worker reentry intervals for vegetable insecticides.

Pesticides may be identified by common chemical names (not capitalized) or by trade names (capitalized). Because one or more manufacturers may assign different trade names to products containing the same active ingredient, two or more commercial insecticides may be virtually identical. The tables in this chapter list insecticides by common chemical name, with trade names added in parentheses.

Where insecticides must be used, several important steps help to assure safety and effectiveness. Applicators must read and follow label instructions. Labels specify maximum application rates, the maximum number of applications, and the preharvest interval (PHI). Labels also specify the crops on which an insecticide can be applied; application to crops or sites not specified on the label is illegal and can result in fines and/or imprisonment. To document the legal use of insecticides, producers should keep records of insecticide applications for every field. Records should include the trade name, the identity and concentration of active ingredient in the product, the dilution used, the rate of application per acre, and the date for each application.

Pesticides classified for restricted use (identified in this chapter by an asterisk) can be purchased only by a licensed private or commercial pesticide applicator and applied only by or under the direct supervision of a licensed applicator. The Illinois Department of Agriculture (IDA) is responsible for testing and licensing pesticide applicators; contact an IDA office or local Extension office for information on training and examination programs. Farmers may apply general-use pesticides (not restricted) according to label directions without obtaining a private applicator's license. Whenever any pesticides are used, applicators must use proper safety precautions to prevent excessive or unnecessary exposures that might endanger themselves, other workers, or family members. After pesticides are applied, reentry restrictions must be observed (see Table 3).

The list of insecticides registered for use on specific crops can change at any time during the year. Announcements of label changes are made through newsletters and other media outlets. Producers should also check with local Extension educators for information updates.

In addition to the use of insecticides, integrated management programs for vegetable insects should include appropriate cultural practices (such as the selection of resistant varieties, the purchase of insect-free transplants, and the destruction of crop residues after harvest) and the use of alternatives to chemical insecticides when possible. For details on alternatives, see North Central Regional Publication 401, *Alternatives in Insect Management: Biological and Biorational Approaches*, available for $6.00 from the Office of Agricultural Communications and Education, 69 Mumford Hall, 1301 Gregory Drive, Urbana, IL 61801. Make checks payable to the University of Illinois. Although using effective cultural and biological control options does not eliminate the need for conventional insecticides, the application of such products can be reduced on farms where an integrated approach is practiced.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
ASPARAGUS			
Asparagus beetle (NHE-49)			Treat spears during the harvest season if infestations exceed 5 to 10 adults per 100 crowns or if eggs are present on more than 2 percent of the spears. Treat ferns postharvest if infestations exceed 5 to 10 adults per 10 crowns.
	carbaryl (Sevin)	1 to 2 lb	1 day.
	chlorpyrifos (Lorsban)	1 lb	1 day.
	permethrin (Ambush or Pounce)	0.05 to 0.1 lb	1 day. Do not exceed 0.4 lb a.i./acre/season.
	malathion	1 lb	1 day.
	rotenone	Follow label directions.	1 day.
Cutworms (NHE-38)	chlorpyrifos (Lorsban)	1 lb	1 day.
	*permethrin (Ambush or Pounce)	0.1 lb	1 day. Do not exceed 0.4 lb a.i./acre/season.
Asparagus aphid			Rarely a serious pest in the Midwest. Treat ferns with rotenone, malathion, or chlorpyrifos as listed above for aparagus beetle.
BEANS			
Seed maggots (NHE-27)	chlorpyrifos (Lorsban 50SL)	2 oz/100 lb seed	Seed treatment.
	diazinon 50% WP	1/2 oz/bu seed	Apply as a planter box treatment. Alternatively, purchase seed that has been pretreated. Seed treatments should not be applied earlier than 90 days before planting.
Bean leaf beetle (NHE-67)			Treat foliage as needed; peak numbers of beetles occur in late May–early June, then again in August–September.
	carbaryl (Sevin)	1 lb	0 days.
	acephate (Orthene)	0.5 to 1.0 lb	14 days. (0 days for lima beans.) Do not use treated vines for feed.
	rotenone	0.4 lb	1 day.
Leafhoppers (NHE-22) and plant bugs (NHE-68)			Treat if populations exceed 1 adult per sweep or 1 nymph per 10 leaves. For plants smaller than the 2-true-leaf stage, treat if counts exceed 1 adult per 2 sweeps.
	carbaryl (Sevin)	1 lb	0 days.
	dimethoate (Cygon)	0.25 to 0.5 lb	0 days. Do not use treated vines for feed.
	esfenvalerate (Asana)	0.03 lb	3 days. Do not exceed 0.2 lb a.i./acre/season. Do not use treated vines for feed.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
BEANS (cont.) Leafhoppers (cont.)	malathion	1 lb	1 day.
	*methomyl (Lannate)	0.45 lb	3 days. 7-day PHI for feeding treated vines to livestock.
	*methyl parathion (Penncap-M)	0.5 to 1 lb	3 days.
Mexican bean beetle (NHE-151)			An occasional pest in mid- to late season. Treat foliage if lacework feeding is prevalent.
	carbaryl (Sevin)	0.5 to 1 lb	0 days.
	malathion	1 lb	1 day.
	acephate (Orthene)	0.5 to 1 lb	14 days. (0 days for lima beans.) Do not use treated vines for feed.
Aphids (NHE-47)			Treat when aphids are present on most plants, but before leaves begin to curl or deform.
	dimethoate (Cygon)	0.25 to 0.5 lb.	0 days. Do not use treated vines for feed.
	malathion	1 lb	1 day.
	acephate (Orthene)	0.5 to 1 lb	14 days. (0 days for lima beans.) Do not use treated vines for feed.
	*methomyl (Lannate)	0.45 lb	3 days. 7-day PHI for feeding treated vines to livestock.
Blister beetles (NHE-72)	carbaryl (Sevin)	0.5 to 1 lb	0 days. Treat foliage as needed in mid- to late season.
Corn earworm (NHE-33)			Treat to prevent pod contamination, usually after August 20.
	carbaryl (Sevin)	1.5 lb	0 days.
	*methomyl (Lannate)	0.45 lb	3 days. 7-day PHI for feeding treated vines to livestock.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	3 days. Do not exceed 0.2 lb a.i./acre/ season. Do not use treated vines for feed.
European corn borer (NHE-140)			Treat snap beans to prevent pod boring and contamination. Borers present before bloom usually do not cause economic damage.
	acephate (Orthene)	1 lb	14 days. Do not use treated vines for feed.
	carbaryl (Sevin)	1.5 lb	0 days.
	*methomyl (Lannate)	0.45 lb	3 days. 7-day PHI for feeding treated vines to livestock. Must be applied at 2- to 3-day intervals.
	methyl parathion (Penncap-M)	0.5 lb to 1 lb	3 days.
Spider mites			Mite outbreaks are rare in beans under sprinkler irrigation; outbreaks may occur in late season during prolonged dry periods.
	dimethoate (Cygon)	0.25 to 0.5 lb	0 days. Do not use treated vines for feed.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
PEAS			
Caterpillars, including loopers (NHE-76, 77)			Treat before harvest if necessary to prevent contamination.
	*methomyl (Lannate)	0.45 to 0.9 lb	1 day. 5-day PHI for livestock forage; 14-day PHI for pea vine hay.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	3 days. Do not exceed 0.1 lb a.i./acre/season. Do not use treated vines for feed.
Aphids (NHE-14, 47)	dimethoate (Cygon)	0.17 lb	0 days. 21-day PHI if treated vines are to be used for livestock feed. Limit of 1 application per season.
BROCCOLI, BRUSSELS SPROUTS, CABBAGE, AND CAULIFLOWER			
Cabbage maggot (NHE-44)			Use in-furrow or broadcast applications of diazinon or Dyfonate at or just before planting. Use drenches of diazinon or Lorsban during transplanting. Diazinon resistance has been observed in some areas.
	diazinon	3 lb	Broadcast and incorporate before planting.
	*fonofos (Dyfonate)	2 lb	Broadcast and incorporate before planting.
	chlorpyrifos (Lorsban)	1.6 to 2.4 fl oz 4EC in 50 gal water/1,000 row ft of broccoli, brussels sprouts, or cabbage. 1.6 to 2.8 fl oz 4EC in 50 gal water/1,000 row ft of cauliflower.	30 days. Apply to soil at base of transplants immediately after setting.
	diazinon	0.25 to 0.5 pint AG500 or 0.25 to 0.5 lb 50% WP in 50 gal water. Use 1/2 to 1 cup per plant.	Apply to soil at base of transplants immediately after setting.

Scouting for aphids and foliage-feeding caterpillars: Check 10 to 20 randomly selected plants in each of 5 or more areas per field. For each plant, record the presence of any live larvae of diamondback moth, cabbage looper, or imported cabbage worm; classify each plant as infested or uninfested (note which species); for each plant also record whether or not aphids are present. Treat if the percentage of plants infested by caterpillars exceeds the following levels for specific stages of development:

Broccoli and Cauliflower:

Seed bed	10%
Transplant to first flower or first curd	50%
Flower bud or curd to harvest	10%

Cabbage:

Seed bed	10%
Transplant to cupping	30%
Cupping to early head	20%
Mature head	10%

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
BROCCOLI, BRUSSELS SPROUTS, CABBAGE, AND CAULIFLOWER (cont.) Other scouting guidelines have also been proposed; contact the Office of Agricultural Entomology at (217) 333-6651 for more information. Aphid control is recommended for cabbage whenever 1 percent or more of the plants are infested. Control often can be delayed in broccoli and cauliflower until "clean-up" is necessary just before heading to prevent contamination at harvest. Aphid control in seed beds is especially important for all of these crops.			
Aphids (NHE-47)	dimethoate (Cygon)	0.25 to 0.5 lb	7 days broccoli and cauliflower; 3 days cabbage. Do not use on brussels sprouts.
	*methamidophos (Monitor)	0.5 to 1.0 lb	14 or 21 days broccoli; 14 days brussels sprouts; 28 days cauliflower; 35 days cabbage.
	naled (Dibrom)	1 lb	1 day
	endosulfan (Thiodan)	1 lb	7 days broccoli and cabbage; 14 days brussels sprouts and cauliflower. Do not exceed 2 applications per season.
	*mevinphos (Phosdrin, Mevinphos 400)	0.1 to 1lb	1 to 3 days for broccoli and cabbage; 3 to 7 days for brussels sprouts and cauliflower.
	insecticidal soap (M-Pede)	1.25 fl oz 49% concentrate/50 gal water. See comments.	0 days. Use sufficient spray to wet all infested plant surfaces. Repeat 1 to 2 times/week. Rotate sprays or rinse foliage to avoid more than 3 consecutive sprays. Must contact aphids to be effective.
	oxydemetonmethyl (MetaSystox-R)	0.375 to 0.5 lb	10 days brussels sprouts; 7 days broccoli, cabbage and cauliflower. Do not exceed 3 applications per season.
Cabbage looper (NHE-45); diamondback moth; imported cabbage worm			Thorough coverage is important; some labels recommend wetting agents. In some areas, diamondback moth has become resistant to permethrin, methomyl, endosulfan, and other compounds; resistance levels vary within the state and locally. Use *Bt* products where resistance has developed to these compounds or to slow resistance development.
	Bacillus thuringiensis kurstaki (Bt) (Dipel, Javelin, MVP, Biobit, Xentari, Agree, and others)	Follow label directions.	0 days. Kills only the caterpillar stage; must be eaten by larvae to be effective. Do not tank-mix *Bt* with dimethoate.
	*permethrin (Ambush, Pounce)	0.05 to 0.1 lb for broccoli, brussels sprouts, and cauliflower. 0.05 to 0.2 lb for cabbage.	1 day. Do not exceed 0.8 lb a.i./acre/season on broccoli, brussels sprouts, and cauliflower. Do not exceed 1 lb a.i./acre/season on cabbage.
	*methomyl (Lannate)	0.23 to 0.9 lb	3 days broccoli, brussels sprouts, cauliflower; 1 day cabbage. Also aids in aphid control.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
BROCCOLI, BRUSSELS SPROUTS, CABBAGE, AND CAULIFLOWER (cont.)			
Cabbage looper and other caterpillars (cont.)	*methamidophos (Monitor)	0.5 to 1 lb	14 or 21 days broccoli; 14 days brussels sprouts; 28 days cauliflower; 35 days cabbage.
	endosulfan (Thiodan)	1 lb	7 days broccoli and cabbage; 14 days brussels sprouts and cauliflower. Do not exceed 2 applications per season.
	*mevinphos (Phosdrin, Mevinphos 400)	0.25 to 1 lb	1 to 3 days for broccoli and cabbage; 3 to 7 days for brussels sprouts and cauliflower.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	3 days. Do not use on brussels sprouts. Do not exceed 0.4 lb a.i./acre/season. Not labeled for diamondback moth.
	thiodicarb (Larvin)	0.4 to 1 lb	7 days. Do not use on brussels sprouts. Do not exceed 6 lb a.i./acre/season.
Cutworms	*esfenvalerate (Asana)	0.03 to 0.05 lb	3 days. Apply as basal spray after planting if cutworm damage occurs. Do not use on brussels sprouts. Do not exceed 0.4 lb a.i./acre/season.
Flea beetles			Except for *Bacillus thuringiensis*, insecticides used to control cabbage looper and other caterpillars listed above will also control flea beetles.
	carbaryl (Sevin)	0.5 to 1 lb	3 days.
	rotenone	0.4 lb.	1 day.
Thrips (NHE-48)			Thrips control may be necessary as heads begin to form. Cygon or Monitor used for aphid control will also kill thrips.
RADISHES AND TURNIPS (roots)			
Cabbage maggot (NHE 44)			Use in-furrow applications at planting for radishes and turnips. Also apply a diazinon drench to turnips 30 days after planting.
	chlorpyrifos (Lorsban)	1 fl oz 4E or 3.3 oz. 15% G per 1,000 row ft	Apply only at planting. Use 4E as a drench (minimum of 40 gal water/acre); place 15% G in seed furrow.
	diazinon	2.5 oz 14% G per 1,000 row ft	Apply only at planting; place in seed furrow.
	diazinon	0.5 lb	10 days. For turnips, apply as a drench over the row 30 days after planting. Also controls flea beetles.
Aphids (NHE-47) and flea beetles	diazinon	0.5 lb	10 days.
	malathion	1 lb	7 days. Not labeled against flea beetles.
	carbaryl (Sevin)	1 lb	3 days. Will not control aphids.
	dimethoate (Cygon)	0.25 lb	14 days. Turnips only. May not control flea beetles.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
COLLARDS, KALE, MUSTARD GREENS, AND TURNIP GREENS			
Aphids (NHE-47)			
	diazinon	0.5 lb	10 days collards, kale, and turnip greens. Do not apply to mustard greens.
	dimethoate (Cygon)	0.25 lb	14 days.
	*mevinphos (Phosdrin, Mevinphos 400)	0.25 lb	3 days.
	naled (Dibrom)	1 lb	1 day collards and kale. Do not apply to mustard greens or turnip greens.
	insecticidal soap (M-Pede)	1.25 fl oz 49% concentrate/50 gal water. See comments.	0 days. Use sufficient spray to wet all infested plant surfaces. Repeat 1 to 2 times/week. Rotate sprays or rinse foliage to avoid more than 3 consecutive sprays. Must contact aphids to be effective.
Cutworms	carbaryl (Sevin)	2 lb	14 days.
Leafhoppers	carbaryl (Sevin)	0.5 to 1 lb	14 days.
	dimethoate (Cygon)	0.25 lb	14 days.
	malathion	1 lb	7 days.
Cabbage looper (NHE-45); diamondback moth; imported cabbageworm			Treat when larvae are small; repeated applications every 4 to 7 days are often necessary. Thorough coverage is necessary; some labels recommend wetting agents. In some areas, diamondback moth has become resistant to permethrin, methomyl, endosulfan, and other compounds; resistance levels vary within the state and locally. Use *Bt* products where resistance to these compounds has developed or to slow resistance development.
	Bacillus thuringiensis kurstaki (Bt) (Dipel, Javelin, MVP, Biobit, and others)	Follow label directions.	0 days. Kills only the caterpillar stage; must be eaten by larvae to be effective. Do not tank-mix *Bt* with dimethoate.
	permethrin (Ambush, Pounce)	0.05 to 0.1 lb	1 day collards and turnip greens. Do not apply to kale or mustard greens. Do not exceed 8 applications to collards or 4 applications to turnip greens.
	methomyl (Lannate)	0.45 to 0.9 lb	10 days. Also aids in aphid control.
	naled (Dibrom)	1 to 2 lb	1 day.
	*mevinphos (Phosdrin, Mevinphos 400)	0.25 lb	3 days.
	endosulfan (Thiodan)	0.75 lb	21 days collards, kale, and mustard greens; apply only once per season. Do not use on turnips.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
Flea beetles			Except for *Bacillus thuringiensis*, insecticides used to control cabbage looper and the other caterpillars listed above will also kill flea beetles.
	carbaryl (Sevin)	1 lb	14 days.
HORSERADISH			
Diamondback moth			Populations build in late summer, but rarely warrant control. Horseradish tolerates substantial feeding (removal of greater than 30 percent of leaf tissue) by diamondback moth without reduction in yield (root growth). If treatment is warranted, thorough coverage is necessary; some labels recommend wetting agents. In some areas, diamondback moth has become resistant to permethrin, methomyl, endosulfan, and other compounds; resistance levels vary within the state and locally. Use *Bt* products where resistance to these compounds has developed or to slow resistance development.
	Bacillus thuringiensis kurstaki (Bt) (Dipel, Javelin, MVP, Biobit, and others)	Follow label directions.	0 days. Kills only the caterpillar stage; must be eaten by larvae to be effective.
	*permethrin (Pounce, Ambush)	0.1 lb	22 days. Do not exceed 3 foliar applications per season.
Beet leafhopper			Treat when migrating beet leafhoppers are collected (usually July–August) or when brittle root is detected in fields.
	*permethrin (Ambush, Pounce)	0.1 lb	22 days. Do not exceed 3 foliar applications per season.
	*methomyl (Lannate)	0.45 lb	65 days.
Imported crucifer weevil	*permethrin	0.1% a.i. solution	At planting. Soak sets 30 minutes and air dry before planting.
	*permethrin	0.2 lb	22 days. Do not exceed 3 foliar applications per season.
LEAF LETTUCE, SPINACH, AND SWISS CHARD			
Aphids and leafminers	diazinon	0.25 to 0.5 lb	10 days lettuce and spinach; 12 days Swiss chard.
	dimethoate (Cygon)	0.25 lb	14 days.
	insecticidal soap (M-Pede)	1.25 fl oz 49% concentrate/50 gal water. See comments.	0 days. Use sufficient spray to wet all infested plant surfaces. Repeat 1 to 2 times/week. Rotate sprays or rinse foliage to avoid more than 3 consecutive sprays. Must contact aphids to be effective.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
LEAF LETTUCE, SPINACH, AND SWISS CHARD (cont.)			
Leafhoppers	carbaryl (Sevin)	0.5 to 1 lb	14 days.
	dimethoate (Cygon)	0.25 lb	14 days.
	malathion	1 lb	14 days leaf lettuce; 7 days spinach and Swiss chard.
Caterpillars, including loopers			See comments under "**Broccoli, . . .**" regarding diamondback moth resistance to permethrin, methomyl, and endosulfan.
	Bacillus thuringiensis kurstaki (Bt) (Dipel, Javelin, MVP, Biobit, others)	Follow label directions.	0 days. Kills only the caterpillar stage; must be eaten by larvae to be effective. Do not tank-mix *Bt* with dimethoate.
	*methomyl (Lannate)	0.45 to 0.9 lb	7 days spinach; 10 days lettuce and Swiss chard. Also aids in aphid control.
	*permethrin (Ambush, Pounce)	0.1 to 0.2 lb	1 day. Do not exceed 2.0 lb a.i./acre/season. Do not feed or graze treated plants.
	thiodicarb (Larvin)	0.4 to 0.75 lb	14 days. Do not exceed 1.5 lb a.i./acre/season.
Flea beetles	carbaryl (Sevin)	1 lb	14 days.
CUCUMBERS, MELONS, PUMPKINS, AND SQUASH			
			To reduce bee kill in vine crops, apply insecticides only late in the day after blossoms have closed.
Striped and spotted cucumber beetles (NHE-46)			Control striped and spotted cucumber beetles to prevent bacterial wilt in cucumbers and muskmelon. In these crops, treat if beetle infestations exceed 4 to 5 per 50 plants.
	carbaryl (Sevin)	1 lb	0 days. Sevin XLR is the formulation of carbaryl that is least toxic to honey bees.
	*carbofuran (Furadan 15G)	2 lb	Band apply to soil at planting.
	permethrin (Ambush, Pounce)	0.1 to 0.2 lb	0 days. Do not exceed 1.6 lb a.i./acre/season.
Aphids (NHE-47)	malathion	1 lb	1 day cucumbers, melons, and squash; 3 days pumpkins.
	diazinon	0.5 lb	7 days cucumbers and summer squash; 3 days melons and winter squash. Do not apply to pumpkins.
	dimethoate (Cygon)	0.25 lb	3 days, melons only. Do not apply to cucumbers, pumpkins, or squash.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
CUCUMBERS, MELONS, PUMPKINS, SQUASH (cont.)			
Aphids (cont.)	endosulfan (Thiodan)	0.5 to 1 lb	2 days cucumbers, melons, and squash; 1 day pumpkins. Do not exceed 3 lb a.i./-acre/year. Also controls cucumber beetles, aids in controlling squash bug and squash vine borer.
Squash bug (NHE-51)			Treat when first eggs begin to hatch (around June 15 to July 15).
	*permethrin (Ambush, Pounce)	0.2 lb	0 days. Do not exceed 1.6 lb a.i./acre/season.
	trichlorfon (Dylox)	1 lb	3 days, pumpkins only. Do not exceed 3 applications per season. Do not apply to cucumbers, melons, or squash.
Leafhoppers	*permethrin (Ambush, Pounce)	0.2 lb	0 days. Do not exceed 1.6 lb a.i./acre/season.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	3 days. Do not exceed 0.25 lb a.i./acre/season.
	dimethoate (Cygon)	0.25 lb	3 days, melons only. Do not apply to cucumbers, pumpkins, or squash.
Squash vine borer (NHE-8)			Treat base of stems (3 feet) weekly when vines begin to run, usually 5 applications.
	carbaryl (Sevin)	1 lb	0 days.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	3 days. Do not exceed 0.25 lb a.i./acre/season.
Pickleworm			Begin weekly sprays in mid-August if necessary. Not a common problem.
	carbaryl (Sevin)	1 lb	0 days.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	3 days. Do not exceed 0.25 lb a.i./acre/season.
	endosulfan (Thiodan)	0.5 to 1 lb	2 days cucumbers, melons, and squash; 1 day pumpkins. Do not exceed 3 lb a.i./-acre/season. Also controls cucumber beetles; aids in controlling squash bug and squash vine borer.
Mites	dimethoate (Cygon)	0.25 lb	3 days, melons only. Do not apply to cucumbers, pumpkins, or squash.
	dicofol (Kelthane)	0.35 to 0.6 lb	2 days. Apply in 40 to 100 gal water/acre.
Cutworms			Treat at plant emergence or transplanting if cutworm damage occurs.
	carbaryl	2 lb	0 days.
	*permethrin (Ambush, Pounce)	0.1 to 0.2 lb	0 days. Do not exceed 1.6 lb a.i./acre/season.
	*esfenvalerate (Asana)	0.05 lb	3 days. Do not exceed 0.25 lb a.i./acre/season.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
ONIONS			
Onion maggot (NHE-50)			Use soil insecticides as furrow or broadcast applications at or just ahead of planting. If diazinon is used, supplement by treating foliage when first adult flies are seen and again 1 week later.
	*fonofos (Dyfonate)	2 to 4 lb	In furrow at planting.
	chlorpyrifos (Lorsban)	1 lb	In furrow at planting. (Granular or EC formulations)
	diazinon	1 lb	Preplant broadcast. Incorporate 1 to 2 inches by disking. Supplement with foliage spray.
	diazinon	0.5 lb	10 days. Apply to foliage when first adults (flies) are present.
	malathion	1 lb	3 days. Apply to foliage when first adults (flies) are present.
Thrips (NHE-48)			Mid- to late-season pests; treat when injury appears and at 10-day intervals as needed.
	*methomyl (Lannate)	0.45 lb	7 days. Wetting agent recommended.
	diazinon	0.5 lb	10 days.
	malathion	1 lb	3 days.
	*methyl parathion (Penncap-M)	0.5 lb	15 days.
	*azinphosmethyl (Guthion)	0.5 lb	28 days dry onions. 14 days green onions. Do not exceed 3 applications per season. 25W and 2S formulations are not restricted-use. Some thrips populations are resistant.
	*permethrin (Ambush, Pounce)	0.15 to 0.3 lb	1 day. Dry bulb onions only. Do not exceed 2.4 lb a.i./acre/season.
PEPPERS			
Aphids (NHE-47)			Lady beetles, green lacewings, and parasitoids often control green peach aphids. Treat only if necessary.
	dimethoate (Cygon)	0.25 lb	0 days.
	*methomyl (Lannate)	0.45 lb	3 days.
	acephate (Orthene)	0.5 to 1 lb	7 days.
	insecticidal soap (M-Pede)	1.25 fl oz 49% concentrate/50 gal water. See comments.	0 days. Use sufficient spray to wet all infested plant surfaces. Repeat 1 to 2 times/week. Rotate sprays or rinse foliage to avoid more than 3 consecutive sprays. Must contact aphids to be effective.
European corn borer	acephate (Orthene)	1 lb	7 days. If borers are present when the crop is fruiting, treat every 5 days.
	*permethrin (Ambush, Pounce)	0.2 lb	3 days. Do not exceed 1.6 lb a.i./acre/season.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
PEPPERS (cont.)			
Flea beetle	*esfenvalerate (Asana)	0.03 to 0.05 lb	7 days. Do not exceed 0.35 lb a.i./acre/season. Early season pest.
	acephate (Orthene)	0.5 lb	7 days.
POTATOES Colorado potato beetle; cutworms; flea beetles; potato leafhopper (NHE-22)			Populations of Colorado potato beetle are resistant to one or more insecticides in some areas. Field kits for detecting insecticide resistance are available from Michigan State University. Contact the University of Illinois Office of Agricultural Entomology at (217) 333-6651 for information. If registered insecticides fail to give control, switch to another insecticide class. *Bacillus thuringiensis san diego (= Bt tenebrionis)* is a new option for controlling Colorado potato beetle larvae (not adults). Rotate crops to delay infestations.
	*phorate (Thimet G)	2 to 3 lb	90 days. Place at side(s) of row at planting, but not in direct contact with seed pieces. Low rate on light soils; high rate on heavier soils; do not use on muck soils. Not labeled for cutworms. Also aids in aphid control.
	carbaryl (Sevin)	2 lb (4 lb for cutworms)	0 days.
	*permethrin (Ambush, Pounce)	0.05 to 0.2 lb	7 days. Do not exceed 2.4 lb a.i./acre/season.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	7 days. Do not exceed 0.35 lb a.i./acre/season.
	*carbofuran (Furadan)	0.5 to 1 lb	14 days. Do not apply more than 8 times per season. Not labeled for cutworms.
	Bacillus thuringiensis san diego (= Bt tenebrionis) (M-One and Trident II)	Follow label directions.	0 days. For Colorado potato beetle only. These strains of *Bt* kill only the early larval stages of Colorado potato beetle; they will not kill adults.
	rotenone	Follow label directions.	1 day. For Colorado potato beetle and flea beetles.
Aphids (NHE-47)	dimethoate (Cygon)	0.25 lb to 0.5 lb	0 days. Also controls leafhoppers.
	*methomyl (Lannate)	0.45 to 0.9 lb	6 days. Also controls leafhoppers and flea beetles.
	*methamidophos (Monitor)	0.75 to 1 lb	14 days. Also controls Colorado potato beetle, potato leafhopper, and flea beetles.
	insecticidal soap (M-Pede)	1.25 fl oz 49% concentrate/50 gal water. See comments.	0 days. Use sufficient spray to wet all infested plant surfaces. Repeat 1 to 2 times/week. Rotate sprays or rinse foliage to avoid more than 3 consecutive sprays. Must contact aphids to be effective.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
Potatoes (cont.) Blister beetles (NHE-72)	carbaryl (Sevin)	0.5 to 1 lb	0 days.
Wireworms (NHE-43); white grubs (NHE-23)	*phorate (Thimet G)	2 to 3 lb	90 days. Place at side(s) of row at planting, but not in direct contact with seed pieces. Low rate on light soils; high rate on heavier soils; do not use on muck soils.
	(Dyfonate and Mocap also are labeled for wireworm control but not for white grubs.)		
SWEET CORN Corn rootworms (NHE-26)			Crop rotation (with corn following any crop except corn) prevents damage from corn rootworms. Apply a soil insecticide if corn is planted in the same field as last year AND no earworm/corn borer control programs were followed. (Where foliar insecticides were used fairly often for earworms or corn borers in sweet corn, they also controlled rootworm beetles and prevented egg laying.)
	*terbufos (Counter G)	1 lb	In furrow or band at planting.
	*fonofos (Dyfonate G)	1 lb	"
	chlorpyrifos (Lorsban G)	1 lb	"
	*ethoprop (Mocap G)	1 lb	"
	*phorate (Thimet G)	1 lb	"
Cutworms (NHE-38)			Use postemergence sprays at the 3- to 5-leaf stage if damage occurs and cutworms are present. Ground applications to the base of plants are most effective.
	chlorpyrifos (Lorsban)	1 to 1.5 lb	35 days.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	1 day.
	*permethrin (Ambush, Pounce)	0.1 to 0.2 lb	1 day. Do not exceed 1.2 lbs a.i./acre/season.
Flea beetles (NHE-36)	carbaryl (Sevin)	1 to 2 lb	0 days.
	chlorpyrifos (Lorsban)	1 to 1.5 lb	35 days.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	1 day.
	*permethrin (Ambush, Pounce)	0.1 to 0.2 lb	1 day. Do not exceed 1.2 lbs a.i./acre/season.
	*carbofuran (Furadan)	1 lb.	Apply in furrow at planting. Apply if overwintering flea beetle populations are high and varieties that are susceptible to Stewart's wilt must be used.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
SWEET CORN (cont.)			
Japanese beetle (NHE-32)	carbaryl (Sevin)	1 lb	0 days. Control beetles if silk clipping threatens pollination. Ground-applied sprays directed to the ear zone are most effective. Sprays (except *Bt*) used for corn earworm or European corn borer will control Japanese beetle if it is present.
European corn borer (NHE-140)		Because sweet corn planting dates vary over a period of several weeks, a range of plant stages may be attacked by first and second generation borers (usually in June, then late July–August, respectively). Plant maturity at the time of attack (not the generation of corn borer) determines the type of damage and the appropriate insecticides for control. See also the insecticides listed for corn earworm control if applications are to be made during silking.	
Whorl stage corn			Scout for "shot-hole" feeding on leaves and for larvae in whorls. Treat during late whorl if more than 15 percent of plants show larval feeding. Treat before larvae bore from the whorl into the stalk.
	Bacillus thuringiensis kurstaki (Bt) (Dipel, Javelin, MVP, Biobit, and others)	Follow label directions.	0 days. Apply granules by air or ground and liquids by ground sprays with nozzles directly over the whorl. *Bt* kills only larvae, not adult moths; ***Bt* does not adequately protect sweet corn if attack occurs during tasseling and ear formation.**
	*permethrin (Ambush, Pounce)	0.1 to 0.2 lb	1 day. Do not exceed 1.2 lb a.i./acre/season. Apply every 5 days as needed.
	carbaryl (Sevin)	2 lb	0 days.
Tassel emergence through harvest			*Processing corn:* Observe light traps for corn borer moths. Treat if counts exceed 50 moths/trap/night. Treat every 5 to 7 days until 10 to 12 days before harvest. Fresh-market corn: Treat once at tasseling; later sprays for corn earworm will control corn borers.
	*permethrin (Ambush, Pounce)	0.1 to 0.2 lb	1 day. Do not exceed 1.2 lb a.i./acre/season. Apply every 5 days as needed.
	*methyl parathion (Penncap-M)	0.5 to 1 lb	3 days. 12 days forage or grazing. Avoid treating during pollen shed to reduce bee injury. (Not highly effective against corn earworm.)
	*methomyl (Lannate)	0.23 to 0.45 lb	0 days. 3 days forage or grazing. Re-treat at 1- to 3-day intervals. Apply by ground with sprays directed to ear zone.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
SWEET CORN (cont.)			
Tassel emergence through harvest (cont.)	*carbofuran (Furadan)	0.5 lb	7 days. 21 days forage or grazing. **For machine-harvested fields only! Worker reentry interval is 14 days!** Do not exceed 4 applications per season. (Do not use for corn earworm control.)
Corn earworm (NHE-33)			*Fresh-market corn:* If traps are capturing earworm moths, treat at 2- to 4-day intervals from first silk until 90% or more of the silks are brown (usually 4 to 6 applications). *Processing corn:* During silking, observe pheromone traps; if counts exceed 10 moths/trap/night, apply Ambush, Pounce, or Lannate as listed for corn borers during early silking. Retreat every 2 to 5 days during silking using an insecticide listed below if traps continue to capture moths.
	*methomyl (Lannate)	0.23 to 0.45 lb	0 days. 3 days forage or grazing. Apply by ground to ear zone.
	*permethrin (Ambush, Pounce)	0.1 to 0.2 lb	1 day. Do not exceed 1.2 lb a.i./acre/season. Apply by ground to ear zone.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	1 day. Do not exceed 0.5 lb a.i./acre/season. Apply by ground to ear zone.
	carbaryl (Sevin)	2 lb	0 days. Apply by ground to ear zone. During pollen shed, apply late in the day to reduce bee kill. Sevin XLR is less hazardous to bees than Sevin wettable powder.
Sap beetles NHE-40) and picnic beetle	carbaryl (Sevin)	2 lb	0 days. During pollen shed, apply late in the day to reduce bee kill. Sevin XLR is less hazardous to bees than Sevin wettable powder.
	diazinon	1 lb	0 days.
	malathion	1 lb	5 days.
Corn leaf aphid (NHE-29)	malathion	1 lb	5 days.
Fall armyworm (NHE-34)	*methomyl (Lannate)	0.45 lb	0 days. 3 days forage or grazing. Apply by ground to ear zone.
TOMATOES AND EGGPLANTS			
Cutworms (NHE-47)	carbaryl (Sevin)	2 lb	0 days.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	1 day tomato; 7 days eggplant. Do not feed or graze treated vines. Do not exceed 0.5 lb a.i./acre/season.
	trichlorfon (Dylox)	1 lb	21 days tomato. Do not apply to eggplant.
	*methomyl (Lannate)	0.45 lb	1 day tomato; 5 days eggplant.

Table 1. Insecticides Recommended for the Control of Insects in Commercial Vegetable Crops (cont.)

Crop, Pest	Insecticide	Rate (a.i./acre)	Preharvest interval, comments
TOMATOES AND EGGPLANTS (cont.)			
Flea beetles	carbaryl (Sevin)	2 lb	0 days.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	1 day tomato; 7 days eggplant. Do not feed or graze treated vines. Do not exceed 0.5 lb a.i./acre/season.
Aphids (NHE-47)			Treat when aphids are present but before leaves begin to curl.
	diazinon	0.25 lb	1 day tomato. Do not apply to eggplant.
	dimethoate (Cygon)	0.25 lb	7 days tomato. Do not apply to eggplant.
	malathion	1 lb	1 day tomato; 3 days eggplant.
	*methomyl (Lannate)	0.45 to 0.9 lb	1 day tomato; 5 days eggplant.
Cabbage looper	*Bacillus thuringiensis kurstaki (Bt)* (Dipel, Javelin, MVP, Biobit, and others)	Follow label directions.	0 days. Kills caterpillar stage (larvae) only, not adult moths; larvae must eat treated foliage.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	1 day tomato; 7 days eggplant. Do not feed or graze treated vines. Do not exceed 0.5 lb a.i./acre/season.
	*methomyl (Lannate)	0.45 to 0.9 lb	1 day tomato; 5 days eggplant.
Corn earworm (NHE-33); European corn borer (NHE-140); hornworms (NHE-130)			To control these caterpillars in mid- to late summer, insecticides may be added to weekly fungicide sprays beginning at first fruit set if small larvae are present.
	Bacillus thuringiensis kurstaki (Bt) (Dipel, Javelin, MVP, Biobit, and others)	Follow label directions.	0 days. Kills caterpillar stage (larvae) only, not adult moths; larvae must eat treated foliage.
	*esfenvalerate (Asana)	0.03 to 0.05 lb	1 day tomato; 7 days eggplant. Do not feed or graze treated vines. Do not exceed 0.5 lb a.i./acre/season.
	*methomyl (Lannate)	0.45 to 0.9 lb	1 day tomato; 5 days eggplant.
	carbaryl (Sevin)	2 lb	0 days.
Spider mites	dimethoate (Cygon)	0.25 lb	7 days tomato. Do not apply to eggplant.
	dicofol (Kelthane)	0.5 to 0.75 lb	2 days tomato. Do not exceed applications per season. Do not apply to eggplant.
Fruit flies and picnic beetles			Late season pests (August–October). Treat to prevent fruit damage if flies or beetles are present.
	carbaryl (Sevin)	2 lb	0 days.
	diazinon	0.5 lb	1 day tomato. Do not apply to eggplant.

* Use restricted to certified (licensed) applicators only.

Table 2. Minimum Preharvest Intervals (in Days) of Common Insecticides Registered for Use on Vegetable Crops

	acephate (Orthene)	azinphosmethyl (Guthion)	Bacillus thuringiensis kurstaki	Bacillus thuringiensis san diego	carbaryl (Sevin)	carbofuran (Furadan)*	chlorpyrifos (Lorsban)	cryolite (Kryocide)	diazinon (D-Z-N)	dicofol (Kelthane)	dimethoate (Cygon)	disulfoton (Di-Syston)	endosulfan (Thiodan)	esfenvalerate (Asana)*	ethoprop (Mocap)*
Asparagus	..	..	0	..	1	..	1	..	..	..	..	..	..	..	..
Beans (snap)	14	..	0	..	0	..	..	..	7	7	0	P	3	3	..
Beets	..	..	0	..	3	..	..	..	14	..	..	..	..	..	..
Broccoli	..	..	0	..	3	..	P	S	5	..	7	P	7	3	..
Brussel sprouts	14	..	0	..	3	..	P	..	7	..	..	P	14	..	..
Cabbage	..	..	0	..	3	..	P	S	7	..	3	P	7	3	..
Carrots	..	..	0	..	0	..	..	..	10	..	..	..	7	7	..
Cauliflower	14	..	0	..	3	..	P	S	5	..	7	P	14	3	..
Celery	21	..	0	..	14	..	..	..	10	..	..	..	4	..	..
Chinese Cabbage	..	..	0	..	14	..	P	..	..	..	..	P	..	3	..
Collards	..	..	0	..	14	..	P	S	10	..	14	..	21	7	..
Cucumber	..	1	0	..	0	P	..	X	7	2	..	..	2	3	..
Eggplant	..	21	0	0	0	..	..	..	..	..	..	..	1	7	..
Endive, escarole	..	..	0	..	14	..	..	..	10	..	14	..	..	..	..
Horseradish	..	..	0	..	3	..	..	..	..	..	..	..	..	..	..
Kale	..	..	0	..	14	..	P	..	10	..	14	..	21	..	..
Kohlrabi	..	..	0	..	3	..	P	..	..	..	..	..	..	..	..
Lettuce (leaf)	..	..	0	..	14	..	..	S	10	..	14	P	14	..	..
Melons	..	7	0	..	0	P	..	X	3	2	3	..	2	3	..
Mustard greens	..	..	0	..	14	..	..	S	..	..	14	..	21	..	..
Onion, bulb	..	28	0	..	..	..	P	..	10	..	..	..	..	..	..
Onion, green	..	14	0	..	..	..	..	..	..	..	..	..	..	..	..
Parsley	..	..	0	..	14	..	..	..	X	..	..	..	..	..	..
Parsnip	..	..	0	..	3	..	..	..	10	..	..	..	..	..	..
Peas	..	..	0	..	3	..	..	..	0	..	0	..	..	3	..
Pepper	7	21	0	..	0	..	..	X	5	2	0	..	1	7	..
Potato	..	7	0	0	0	14	..	..	35	..	0	30	1	7	P
Pumpkin	..	..	0	..	0	P	..	..	..	2	..	..	1	3	..
Radish	..	..	0	..	3	..	P	..	10	..	..	..	..	7	..
Rhubarb	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Rutabaga	..	..	0	..	3	..	P	..	..	..	..	..	..	..	..
Spinach	..	..	0	..	14	..	..	..	10	..	14	..	21	..	..
Squash (summer)	..	..	0	..	0	P	..	X	3	2	..	..	2	3	..
Squash (winter)	..	..	0	..	0	P	..	..	3	2	..	..	2	3	..
Sweet corn	..	..	0	..	0	7	35	..	0	..	..	..	1	1	P
Swiss chard	..	..	0	..	14	..	..	..	12	..	14	..	..	..	..
Tomato	..	0	0	0	0	..	..	X	1	2	7	P	2	1	..
Turnip, tops	..	..	0	..	14	..	P	..	10	..	14	..	..	..	..
Turnip, roots	..	..	0	..	3	..	P	..	10	..	..	..	..	..	..

Preharvest intervals (PHI) listed are minimums; at maximum application rates, the PHI for some products is greater than the period indicated here. Additional restrictions (limiting the total number of aplications or restricting the use of treated plants for livestock feed) may also apply.

S = apply to seeds or seedlings only; P = apply at or before planting or as early-season side-dress according to label; X = preharvest interval not specified.

*Use restricted to certified (licensed) applicators.

Table 2. Minimum Preharvest Intervals (in Days) of Common Insecticides Registered for Use on Vegetable Crops (cont.)

fonofos (Dyfonate)*	lindane (Isotox)	malathion (Cythion)	metaldehyde	methamidophos (Monitor)*	methomyl (Lannate)*	methoxychlor	methyl parathion (Penncap-M)*	mevinphos (Phosdrin)*	naled (Dibrom)	oxamyl (Vydate)*	*oxydemeton-methyl (MetaSystox-R)	permethrin (Ambush, Pounce)*	phorate (Thimet)*	potassium salt soap (M-Pede)	rotenone	terbufos (Counter)*	thiodicarb (Larvin)	trichlorfon (Dylox, Proxol)
..	..	1	X	..	1	3	..	..	..	..	..	1	..	0	1	..	..	..
P	S	1	X	..	3	3	3	1	1	..	21	..	P	0	1	..	..	..
P	..	7	X	..	0	14	15	3	..	..	..	..	..	0	1	..	..	28
P	S	3	X	14	3	14	7	1	1	..	7	1	..	0	..	..	7	..
P	S	7	X	14	3	14	7	3	1	..	10	1	..	0	..	..	..	..
P	S	7	X	35	1	3	10	1	1	..	7	1	..	0	1	..	7	..
..	..	7	X	..	1	14	15	2	..	P	..	..	..	..	1	..	..	..
P	S	7	X	28	3	7	7	3	1	..	7	1	..	0	..	..	7	..
..	S	7	X	..	7	..	15	3	1	14	..	1	..	0	1	..	14	..
..	..	..	..	..	10	..	..	..	..	..	7	1	..	0	..	..	..	..
..	S	7	X	..	10	14	..	3	1	..	..	1	..	0	..	..	..	..
..	S	1	X	..	1	7	..	1	..	1	X	0	..	0	1	..	..	..
..	..	3	X	..	5	7	..	1	..	1	7	3	..	0	1	..	..	..
..	..	7	X	..	10	..	..	..	..	..	..	1	..	0	..	..	14	..
..	..	7	X	..	65	..	..	..	..	..	..	22	..	0	..	..	..	..
..	S	7	X	..	10	14	..	3	1	..	..	..	..	0	..	..	..	..
..	..	7	X	..	..	7	..	..	..	..	..	..	..	0	..	..	..	..
..	P	14	X	..	..	14	21	7	..	..	..	1	..	0	1	..	14	..
..	S	1	X	..	1	7	..	1	..	1	7	0	..	0	1	..	..	..
..	..	7	X	..	10	..	..	3	..	..	..	..	..	0	..	..	..	..
P	..	3	X	..	7	..	15	..	..	..	30	1	..	0	1	..	..	..
..	..	3	X	..	7	..	15	..	..	..	..	..	..	0	0	..	..	..
..	..	21	..	..	10	..	..	..	..	..	..	1	..	0	..	..	..	..
..	..	7	X	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	3	X	..	1	7	10	1	1	..	..	..	..	0	1	..	..	..
P	..	3	X	..	3	7	15	1	..	7	X	3	..	0	1	..	..	..
P	..	0	X	14	6	0	5	1	..	7	..	7	P	0	1	..	..	..
..	S	3	X	..	..	7	..	..	..	..	14	0	..	0	..	..	..	3
P	..	7	X	..	..	7	..	..	..	..	..	..	..	0	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	14	..
..	..	3	X	..	..	7	..	..	..	..	..	..	..	0	..	..	..	..
..	S	7	X	..	7	14	14	4	..	..	..	1	..	0	1	..	14	..
..	S	1	X	..	1	7	..	1	..	1	1	0	..	0	1	..	..	..
..	S	1	X	..	..	7	..	..	..	..	14	0	..	..	..	..	..	..
P	..	5	X	..	0	7	3	1	..	..	..	1	P	..	1	P	..	0
..	..	7	X	..	10	..	..	..	..	..	..	1	..	0	..	..	14	..
P	P	1	X	7	1	7	10	1	..	1	..	..	..	0	1	..	..	21
..	..	7	X	..	10	14	..	3	..	..	21	..	..	0	..	..	..	..
..	..	7	X	..	..	7	..	3	..	..	7	1	..	0	..	..	..	..

Table 3. Worker Reentry Times for Common Insecticides Used in Vegetable Production

Workers are not to enter a treated field within the specified interval after application unless they are wearing protective clothing, as specified on individual product labels. For most insecticides not listed in this table, unprotected workers should not enter fields after application until sprays have dried or dusts have settled. Regulations on reentry are subject to change; always follow instructions on product labels.

Active ingredient	Trade name(s)	Reentry interval (days)
acephate	Orthene	1
*azinphosmethyl	Guthion	1
*carbofuran	Furadan	14 days sweet corn; 1 day other crops
chlorpyrifos	Lorsban	1
diazinon	Diazinon	1
*disulfoton	Di-Syston	1
endosulfan	Thiodan	1
*fonofos	Dyfonate	1
*methamidophos	Monitor	2
*methomyl	Lannate	2
*methyl parathion	Penncap-M	2
*mevinphos	Phosdrin, Mevinphos 400	2
naled	Dibrom	1
*oxamyl	Vydate	2
*oxydemetonmethyl	MetaSystox-R	2
*phorate	Thimet	2
phosmet	Imidan	1
trichlorfon	Dylox, Proxol	1

* Restricted-use insecticide.

11 Weed Control for Commercial Vegetable Crops

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Weed management requires a multifaceted approach, built upon an understanding of weeds and the crop. Weed management may involve nonchemical methods, chemical methods (herbicides), or a combination of the two. The decision on which methods to use depends on environmental concerns, marketing opportunities, desired management intensity, labor availability, weed pressure, and the crop.

The first step in weed management is to identify the weeds and understand their life cycles. Consult identification guides, such as *Weeds of the North Central States* (Bulletin 772, College of Agriculture, University of Illinois at Urbana-Champaign) for assistance. Weeds can be categorized by life cycles, and management strategies developed accordingly. Annual weeds complete their life cycles in one year and reproduce solely by seeds. Annuals can be divided into summer or winter annuals depending on when they grow. Primary tillage operations often control winter annuals before a crop is planted in the spring. The most common vegetable crop weeds (i.e., barnyardgrass, giant foxtail, common purslane, redroot pigweed, and common lambsquarters) are summer annuals. Mechanical and cultural weed management methods help in suppressing summer annuals. Perennial weeds live for more than two years and can reproduce by seed or vegetative structures (stolons, rhizomes, corms, bulbs, tubers, or roots). Because perennial weeds are impossible to manage in vegetable crops, it is usually better not to use a field with severe perennial weed problems.

There are three sections in this chapter: nonchemical weed management strategies, chemical weed management strategies, and environmental and health hazards of herbicides. Many nonchemical weed management methods are common sense farming practices. These practices are of increasing importance due to consumer concerns about pesticide residues, potential environmental contamination from pesticides, and unavailability of many older herbicides.

Nonchemical Weed Management Strategies

Weed management should start with nonchemical strategies that reduce problems caused by weeds. Their aim should be to manage the weed population so it is below a level which will cause a reduction in your economic return (economic threshold). In some instances, the cost of controlling weeds may be more than the economic return obtained from any yield increase. This situation occurs when a few weeds are present or the weeds germinate late in the season. In those instances, the best strategy may be to do nothing. In other situations weed populations and other considerations may require combining herbicides with nonchemical approaches.

Cultural Practices

You should aim to establish a vigorous crop that competes effectively with weeds. This starts with your *land selection.* A general rule is not to plant vegetables on land with a history of heavy weed infestation, especially of perennial weeds.

Crop selection can reduce the effects of weed competition. One criterion in selecting a crop should be the weed problems of the field. Plant the most competitive crops in the most weed-infested fields and the least competitive crops in the cleanest ones. Consider planting heavily infested fields as long-term set-aside acres or as nonrow crops such as alfalfa. Permanent cover should help prevent buildup of annual weeds.

Crop rotation is another practice that can reduce weed problems. The characteristics of the crop, the methods used to grow it, and the herbicides used inadvertently allow certain weeds to escape control. Rotation also affects the weed management tools at

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The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

your disposal. Rotating between crops will improve growth and the crop's competitiveness. Related vegetables should not be grown in the same location in successive years. Table 1 lists related vegetable crops.

Wild proso millet is an example of a problem weed, for which rotation is an important management tactic. Rotating from sweet corn to small grains, early-planted peas, or alfalfa almost completely eliminates wild proso millet. Alfalfa, early-planted peas, and small grains are established before the soil is warm enough for wild proso millet to germinate. Rotating from sweet corn to broadleaf crops allows use of post-emergence grass herbicides to manage wild proso millet.

Once a crop is selected, use *adaptive vigorous varieties* resistant to diseases. Disease-infested plants cannot effectively compete with weeds. Varieties suited for cultivation in Illinois are listed in *Vegetable Varieties for Commercial Growers* (Circular 1174, University of Illinois at Urbana-Champaign, Cooperative Extension Service).

Narrower row spacings and proper plant densities assure the crop rapidly closes canopy. A closed canopy shades out later emerging weeds and prevents germination of weed seeds requiring light. Weeds seldom are a problem once canopy closure occurs. Proper row spacing and plant density also allow row cultivation.

Table 1. Botanically Related Vegetables

<u>Corn</u>	<u>Cucurbits</u>	<u>Crucifers</u>	<u>Legumes</u>
Sweet corn	Winter squash	Rutabaga	Soybean
Dent corn	Summer squash	Kale	Pea
	Pumpkin	Broccoli	Snap bean
<u>Onions</u>	Muskmelon	Cauliflower	Lima bean
Onion	Watermelon	Cabbage	Dry bean
Garlic		Brussels sprout	
	<u>Solanceous</u>	Radish	
<u>Spinach</u>	Pepper	Horseradish	
Beets	Potato		
Chard	Tomato		
Spinach			

Another cultural method to improve crop competitiveness is to use the *correct planting time.* Crops can be divided into warm- or cool-season plants, depending on the optimum temperature for their growth. The planting date affects the time to emergence and early seedling vigor of the crop, which are important in determining crop competitiveness. Cool-season crops germinate at cooler soil temperatures and thus compete better against early emerging weeds than warm-season crops. Table 2 lists crops according to their adaptation to field temperatures. Time plantings so that temperatures are favorable for crop growth.

Table 2. Classification of Vegetable Crops According to Their Adaptive Field Temperatures

Cool-season		Warm-season	
Hardy*	Semi-hardy	Tender	Very tender
Asparagus	Carrot	Snap bean	Cucumber
Broccoli	Cauliflower	Sweet corn	Eggplant
Cabbage	Chinese cabbage	Tomato	Lima bean
Horseradish	Lettuce		Muskmelon
Onion	Potato		Okra
Peas			Pumpkin
Spinach			Squash
			Watermelon

*Hardy crops are most tolerant of cool temperatures and frost, while very tender crops are most susceptible to frost and cool temperatures.

Adequate fertilization and appropriate insect and disease management are important in assuring a competitive crop. Adequate fertility assures rapid, uniform germination and good crop growth, which enhance the crop's competitive ability. For information on fertility, consult *Fertilizer Guide for Commercial Vegetable Growers* (Circular 1185, University of Illinois at Urbana-Champaign, Cooperative Extension Service). Disease management information is contained in Chapter 12 of this *Handbook*, and insect management information in Chapter 10 of this *Handbook*. While poor insect and disease control reduce a crop's competitiveness, inadequate weed control can also cause insect and disease problems.

Mulching can be useful in managing weeds. Mulches can be classified as either natural (straw, leaves, paper, and compost) or synthetic (plastics). Because natural mulches are difficult to apply over large areas, they are best for small specialized areas. Natural mulches should be spread evenly at least 1-1/2 inches thick over the soil to prevent light penetration. Natural mulch materials must be free of weed seeds and other pest organisms and be heavy enough so they will not be easily displaced by wind or water. A major advantage of natural mulches is that they add organic matter to the soil.

Synthetic mulches control weeds within the row, conserve moisture, increase soil temperature and they are easy to apply. Black plastic mulches are the most common and are particularly effective in improving early-season growth of warm-season crops such as tomatoes, muskmelons, watermelons, or peppers. Better early-season growth of these crops improves their competitive ability against weeds. Plastic mulches used in combination with trickle irrigation also improve water use efficiency.

The biggest disadvantage of plastic mulch is disposing of the plastic since many landfills do not accept them. Photodegradable plastic mulches have been developed, but their season-long persistence has been a problem. Photodegradable mulches also degrade into small pieces of plastic that contaminate the environment. Biodegradable plastic mulches are not yet widely available.

Mechanical Practices

Mechanical weed management relies on primary and secondary tillage implements such as the rotary hoe and the row cultivator. Mechanical weed management starts with seedbed preparation. Few reduced-till systems have been developed for vegetable crops. Reduced-till suggestions are included in the section on herbicides in this chapter.

Moldboard plowing is usually the first step in mechanically managing weeds. It is particularly useful in controlling emerged annual weeds. An important second step is often *rotary hoeing* for mechanically managing weeds in large-seeded vegetable crops (sweet corn, snap beans, lima beans, and peas). Rotary hoeing needs to be done after the weeds germinate but before they emerge. It does not control large-seeded weeds, such as velvetleaf and shattercane.

Once the crop has emerged or transplants are established, a *row cultivator* can be used to manage emerged weeds. Adjust the cultivator sweeps or teeth to dislodge or cover as many weed seedlings as possible. Seedling weeds can be killed by cultivating 1 to 2 inches deep. The best weed control is obtained with a row cultivator in relatively dry soils by throwing soil into the crop row to cover small weed seedlings. Avoid crop injury from poor cultivation, which will reduce crop yields.

In some vegetable crops, such as asparagus, *mowing* can be an effective weed management tool. Mowing can prevent the production of weed seeds and kill upright weeds, reducing competition. Mowing must be carefully timed to prevent the growth of biennial weeds when reducing competition from upright plants. Timely, repeated mowing also helps deplete the food reserves of perennial weeds.

Mechanical control has many limitations that must be considered when designing weed management systems. Because mechanical management relies on relatively dry weather, a rainy period may eliminate mechanical management options and lead to severe weed competition. Relying entirely on mechanical practices to manage weeds is difficult on large acreages. Also, several weeds are extremely difficult to manage unless herbicides are combined with nonchemical approaches. Some of the problem weeds include wild proso millet in sweet corn, Canada thistle, hemp dogbane, field bindweed, quackgrass, and johnsongrass. Newly introduced problem weeds often show up in scattered patches along headlands and field borders. These probably are best controlled or eradicated with herbicides before large areas are infested.

Biological Practices

Currently, no systems using insects or diseases to control weeds common to vegetable crops exist in the Midwest. Most biological management systems using diseases or insects to control problem weeds have centered on rangeland areas in the West. One biological system that has potential in the Midwest is the use of cover crops to suppress the development of weeds. These systems are still experimental, and problems have been encountered. The problems include the duration of weed control from cover crops and the spectrum of weeds controlled. Herbicides are often required to kill the cover crop and to manage any emerged weeds. Overall, cover crop systems tend to control small-seeded annual broadleaf weeds the best. The most promising cover crop system is winter rye. Winter rye is planted in the late summer or early fall; the rye is killed in the spring with Roundup or Poast; and the crop is no-till planted. The system is experimental and should be evaluated in small areas before extensive use.

Table 3 summarizes some of the nonchemical weed management practices. An integrated approach should be used that combines many different practices to manage weeds. This approach must be adaptive, aiming to prevent weed problems or cope with any that occur.

Chemical Weed Management Strategies

Several herbicides are often labeled for a crop. Scouting your area to determine which weeds are present will allow you to select the herbicide that will give you the best control. Potential environmental hazards must be considered when selecting a herbicide. Herbicide labels contain information on these

Table 3. Summary of Nonchemical Weed Management Practices

Practice	Comments
Cultural	
1. Land selection	Avoid fields with history of weed problems.
2. Crop selection	Grow the most competitive crops in fields with history of weed problems.
3. Crop rotation	Rotate between vegetables and nonrow crops such as alfalfa. Rotate between vegetables in different botanical categories.
4. Adapted crop varieties	Select crop varieties adapted for your area.
5. Proper row spacings and plant densities	Use row spacings and plant densities that assure rapid crop canopy closure.
6. Correct planting times	Plant crops when soil temperatures favor rapid germination and emergence. Do not plant warm-season crops too early in the season.
7. Appropriate fertility, disease, and insect management	Vigorous, healthy crops are more competitive against weeds.
8. Mulch	Natural mulches are difficult to use over large acreages. Synthetic (plastic) mulches are useful to manage weeds within the row in warm-season crops. Consider disposal problems when using plastic mulches.
Mechanical	
1. Moldboard plowing	Can eliminate emerged annual weeds.
2. Rotary hoeing	Useful to manage small-seeded weeds in large-seeded crops such as sweet corn, snap beans, lima beans, and peas.
3. Row cultivating	Dislodge or cover as many weed seedlings as possible. Avoid damaging crop root systems.
4. Mowing	Mow weeds as soon as flowers appear so no viable weed seed is produced.
Biological	
1. Cover crops	Still experimental. Winter rye system is the most promising—most effective against small-seeded broadleaf weeds.
2. Insect or disease pests of weeds	No current systems use insects or diseases to manage weeds common to vegetables.

hazards. The last section of this chapter also discusses potential environmental hazards.

All the herbicides labeled for a crop are not necessarily listed below. If you are unfamiliar with a herbicide, conduct a small test under your environmental conditions and cultural practices before using the herbicide extensively.

Always Read and Understand the Herbicide Label Before Use

Reading the herbicide label is a very profitable use of your time. Information on the label will direct you to the correct uses, application methods, rates, and potential environmental hazards. Follow label directions for the best possible control with minimal crop injury and environmental contamination. The label contains restrictions on use and discusses environmental and soil conditions that affect crop injury, influence the effectiveness of weed control, and can cause nontarget site effects.

Use a Herbicide that Is Labeled for Your Particular Use and Crop

Using a nonregistered pesticide can cause harmful residues in the vegetable crop, which can result in crop seizure and consumer injury. The label also states whether the herbicide is a restricted-use or general-use pesticide. Restricted-use pesticide labels contain a statement that the products are restricted, and that only licensed applicators can buy them and supervise their application.

The information in this chapter is current as of the date of publication. Watch for notices of changes in the U.S. Environmental Protection Agency (USEPA) registration of herbicides in the *Illinois Vegetable Farmer's Letter* or the *Pest Management and Crop Development Bulletin.* For subscription information, contact University of Illinois, Agricultural Newsletter Service, 116 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801.

Reduced Tillage Systems

Reduced tillage systems are a method to combat soil erosion. **Roundup** or **Gramoxone Extra** can be applied outside the normal growing season to control emerged weeds in reduced tillage systems. Weeds should be growing actively and the application must be made before the crop has emerged. If you are applying Roundup to control perennial weeds, it is recommended that it be applied before disturbing the soil. After it is applied, Roundup must be allowed to translocate throughout the perennial weed for several days or incomplete control may result. Follow Roundup label directions carefully for the rates and timing of application. If perennial weeds are not a major problem, you can eliminate early flushes of weeds by applying Roundup or Gramoxone Extra to all weeds that emerge. Plant the crop with minimal working of the soil. Never apply Roundup or Gramoxone Extra to an emerged crop because severe crop injury or death will occur.

Roundup and Gramoxone Extra will control most annual broadleaf and grass weeds. Neither herbicide has any soil residual activity, so other weed control measures will be necessary during the growing season. Gramoxone Extra will also suppress perennials by killing their shoots but should not be expected to control regrowth of perennial weeds from rhizomes or other underground storage organs. Roundup is better for controlling perennials because it will kill shoots and translocate to destroy underground parts. Roundup will only suppress some particularly hard-to-control perennials such as bindweed, hemp dogbane, and milkweed. To obtain control of these perennials, applications of high rates, repeat applications of Roundup (within label guidelines), or mechanical removal may be necessary.

How to Use Herbicide Tables

Use Table 4 to determine the herbicides that are labeled for use in your crop. Once you have determined the herbicides available for your crop, use Table 5 to determine which of the labeled herbicides will provide control of the weeds you have present. If you are not certain of the herbicide name, both the common name and the trade names of all herbicides in this chapter are listed in Table 6. These tables are not intended to replace careful reading of a current herbicide label. **Always read the label before applying any pesticide.**

Herbicide Rates and Guidelines for Use in Vegetable Crops

All herbicide rates given in Table 4 are in amount of product per broadcast acre. Adjust amounts accordingly for banded applications. Make preemergence applications before weeds emerge or after removing any weeds present. Make postemergence applications after weeds have emerged. Make stale seedbed treatments only if weeds have emerged but no crop plants are present.

Reregistration of older herbicides has affected the availability of many products. Some of the older herbicides not reregistered are not listed in this chapter but may be available and old stocks can still be used.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops

Herbicide	Rate of product per broadcast acre	Remarks
ASPARAGUS		
Preemergence		
Devrinol (napropamide)	4 to 8 lb of 50WP	Rainfall or irrigation is necessary for activity. Established beds only.
Karmex, others (diuron)	2 to 4 lb of 80WP	Do not apply to young plants during the first year. Two applications per year can be made. See label restrictions.
Lexone or Secor (metribuzin)	1 to 2 qt of 4L or 4F	Established beds only.
Sinbar (terbacil)	1.5 to 3 lb of 80WP	With direct-seeded asparagus, spray activated carbon over rows. High organic soils inactivate Sinbar.
Treflan (trifluralin)	1 to 1.5 pt of 4EC, or 2 to 4 pt of MTF	See label for incorporation instructions. Established beds only.
Postemergence		
2,4-D amine	See label	Apply to actively growing weeds.
Fusilade 2000 (fluazifop-butyl)	32 to 48 fl oz of 1EC	*Nonbearing asparagus only*. Use crop-oil concentrate or a nonionic surfactant. See label for amount.
Poast (sethoxydim)	1 to 1.5 pt of 1.5EC	Use crop-oil concentrate, 2 pt per acre.
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3 pt	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems. Apply at least 1 week before spears emerge, or delay until after harvest.
CARROTS		
Preemergence		
Treflan (trifluralin)	1 to 2 pt of 4EC or MTF	Must be incorporated.
Postemergence		
Fusilade 2000 (fluazifop-butyl)	1 to 1.5 pt of 1EC	Use crop-oil concentrate or nonionic surfactant. Up to 2 applications can be made per year.
Linex or Lorox (linuron)	1.5 to 3 lb of 50DF	Carrots must be at least 3 inches tall. Apply before grasses are 2 inches tall.
Sencor (metribuzin)	0.33 lb of 75DF or 0.5 pt of 4L	See label warnings. Carrots must have at least 5 to 6 leaves. Weeds must be small.
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3 pt	See discussion of reduced tillage systems.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (cont.)

Herbicide	Rate of product per broadcast acre	Remarks
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
COLE CROPS (Broccoli, Brussels Sprout, Cabbage, Cauliflower, and Turnip)		
Preemergence		
Dacthal (DCPA)	8 to 14 lb of 75WP	Can apply to transplants or direct-seeded plants. Not effective on high organic soils. Can be sprayed directly over transplants.
Devrinol (napropamide)	2 to 4 lb of 50WP	Can apply to transplants or direct-seeded plants. Should incorporate shallowly.
Goal (oxyfluorfen)	1.25 to 2.5 pt of 1.6EC	Apply to soil after final tillage but before transplanting. May cause foliar injury. Do not apply to brussels sprout.
Treflan (trifluralin)	1 to 1.5 pt of 4EC or MTF	Direct-seeded cole crops exhibit marginal tolerance to Treflan. Stunting can occur under stress. Must be incorporated.
Postemergence		
Poast (sethoxydim)	1 to 1.5 pt of 1.5EC	Use crop-oil concentrate, 2 pt per acre. Maximum of 3 pt Poast per acre per season. 30 day preharvest interval.
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3 pt	See discussion of reduced tillage systems.
Roundup (glyphosate)	2 to 3 qt	See discussion of reduced tillage systems.
CORN (Sweet and Popcorn)		
Preemergence		
Atrazine		Atrazine is labeled for sweet corn. **Atrazine has been found in surface water and groundwater; it also injures vegetable crops planted after corn. Weed resistance to Atrazine has occurred.**
Bladex (cyanazine)	1.5 to 6.0 lb of 80WP, or 1.3 to 5.3 lb of 90DF, or 1.25 to 4.75 qt of 4L	
Dual (metolachlor)	1.5 to 3 pt of 8EC, or 6 to 12 lb of 25G	Can be incorporated or applied before emergence.
Eradicane Extra (EPTC + safener + extender)	4 to 8 pt of 6.7EC	Will suppress wild proso millet. Must be incorporated. Contains an extender that may lengthen the period of control.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (cont.)

Herbicide	Rate of product per broadcast acre	Remarks
Lasso (alachlor)	2 to 4 qt of 4EC	
Prowl (pendimethalin)	1.5 to 4 pt of 4EC	Do not incorporate. For use on processing varieties. Do not apply prior to planting.
Postemergence		
AAtrex, others (atrazine)	1 to 1.5 pt of 4L, or 1.8 lb of 80WP, or 1.6 lb of Nine-O	Can be applied with crop oils. See label precautions. Do not use after June 10.
Basagran 4S (bentazon)	1.5 to 2 pt	Apply when weeds are small. Consult label for specific directions.
2,4-D amine	See label	Apply to actively growing weeds, preferably before corn is 6 inches tall. See label restrictions. Sweet corn injury may occur.
Poast (sethoxydim)	1 pt of 1.5EC	Post-directed. Minimum corn height 30 inches. Spray should not be above growing point. Use crop-oil concentrate, 2 pt per acre.
Sutan + (butylate + safener)	2.5 to 3.5 qt of 6.7EC	Especially useful on sandy soils. Must be incorporated.
Stale Seedbed		
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
CUCURBITS (Cucumber, Muskmelon, and Watermelon)		
Preemergence		
Alanap (naptalam)	6 to 8 qt of 2L	A second application can be made prior to vining. Normally tank-mixed with Prefar.
Curbit (ethalfluralin)	3 to 4.5 pt of 3EC	Read label carefully before using. Avoid using on cool, wet soils. Requires signing a waiver before using.
Dacthal (DCPA)	6 to 14 lb of 75WP	Apply when the crop is at the 4- to 5-true-leaf stage. For use on direct-seeded cucurbits only.
Prefar (bensulide)	5 to 6 qt of 4EC	Incorporate or irrigate in. Can tank-mix with Alanap. Do not plant other than label-specified crops for 18 months after application.
Postemergence		
Poast (sethoxydim)	1.0 to 2 pt of 1.5EC	Use crop-oil concentrate, 2 pt per acre. Maximum of 3 pt Poast per acre per season. 14 day preharvest interval.
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3 pt	See discussion of reduced tillage systems.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (cont.)

Herbicide	Rate of product per broadcast acre	Remarks
DRY BEANS (White, Navy, Kidney, Pinto, Lima, and Adzuki)		
Preemergence		
Dacthal (DCPA)	8 to 14 lb of 75WP	
Dual (metolachlor)	1.5 to 3 pt of 8EC	
Eptam (EPTC)	2.5 to 3.5 pt of 7EC	Do not use on adzuki beans, cowpeas, lima beans, or other flat pod beans. Incorporate immediately.
Lasso (alachlor)	2 to 3 qt of 4EC	
Prowl (pendimethalin)	1 to 1.5 qt of 4EC	Must be incorporated.
Pursuit (imazethapyr)	3 fl oz of 2EC	Use on lima and red kidney beans only.
Treflan (trifluralin)	1 to 2 pt of 4EC or MTF	Must be incorporated.
Postemergence		
Basagran (bentazon)	1.5 to 2 pt of 4S	Apply when weeds are small. Beans are tolerant after the first trifoliate leaf has expanded.
Poast 1.5E (sethoxydim)	1 to 1.5 pt	Use crop-oil concentrate, 2 pt per acre. Maximum of 4 pt Poast per acre per season. 30 day preharvest interval.
Stale Seedbed		
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
EGGPLANT		
Preemergence		
Dacthal (DCPA)	8 to 14 lb of 75WP	Apply 4 to 6 weeks after transplanting or when direct-seeded plants are 4 to 6 inches tall. Cultivate if weeds have emerged before applying.
Devrinol (napropamide)	2 to 4 lb of 50WP	Transplanted eggplant only.
Postemergence		
Poast (sethoxydim)	1 to 1.5 pt of 1.5EC	Use crop-oil concentrate, 2 pt per acre.
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3 pt	See discussion of reduced tillage systems.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (cont.)

Herbicide	Rate of product per broadcast acre	Remarks
GREENS (Chicory, Collard, Kale, Mustard, Spinach, Turnip Greens)		
Preemergence		
Dacthal (DCPA)	8 to 14 lb of 75WP	For use on collards, kale, mustard, and turnip greens. Not effective on high organic matter soils.
Treflan (trifluralin)	1 to 1.5 pt of 4EC or MTF	Must be incorporated.
Postemergence		
Poast (sethoxydim)	1 to 1.5 pt of 1.5EC	Use crop-oil concentrate, 2 pt per acre. 30 day preharvest interval for all except spinach, which is a 15 day preharvest interval.
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3 pt	Collards only. See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
HORSERADISH		
Preemergence		
Dacthal (DCPA)	8 to 14 lb of 75WP	Apply uniformly to soil at planting time.
Goal (oxyfluorfen)	1.25 to 2.5 pt of 1.6EC	Apply after planting and before emergence. Some crop injury may occur.
Stale Seedbed		
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
LETTUCE		
Preemergence		
Balan (benefin)	3 to 4 qt of 1.5EC	Direct-seeded lettuce only. Must be incorporated.
Kerb (pronamide)	2 to 4 lb of 50WP	Moisture is necessary to activate. Label rates vary depending on variety.
Prefar (bensulide)	5 to 6 qt of 4EC	Can be applied to head and leaf lettuce. Must be incorporated.
Postemergence		
Poast (sethoxydim)	1 to 1.5 pt of 1.5EC	Use crop-oil concentrate, 2 pt per acre.
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3 pt	See discussion of reduced tillage systems.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (cont.)

Herbicide	Rate of product per broadcast acre	Remarks
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
OKRA		
Preemergence		
Treflan (trifluralin)	1 to 2 pt of 4EC or MTF	Must be incorporated immediately after application.
Stale Seedbed		
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
ONION		
Preemergence		
Dacthal (DCPA)	8 to 14 lb of 75WP	Can be applied at planting or at lay-by. Emerged weeds will not be controlled.
Postemergence		
Buctril (bromoxynil)	1 to 1.5 pt of 2EC	Apply when onions have 2 to 5 true leaves. Sensitivity of onions is affected by variety and environment.
Goal (oxyfluorfen)	5 to 10 fl oz of 1.6EC	Do not apply until onions have 2 true leaves. Best control achieved when weeds are in the 2- to 4-leaf stage. Do not apply more than 2.5 pt per broadcast acre in one season.
Fusilade 2000 (fluazifop-P-butyl)	1.25 to 1.5 pt of 1EC	Use nonionic surfactant, 1 pt per acre.
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3 pt	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
PEAS		
Preemergence		
Dual (metolachlor)	1.5 to 3 pt of 8EC	Can be incorporated. See label for restrictions.
Command (clomazone)	1 pt of 4EC	Must be incorporated.
Pursuit (imazethapyr)	3 fl oz of 2EC	Do not use if applying Treflan to peas.
Treflan (trifluralin)	1 to 1.5 pt of 4EC or MTF	Must be incorporated.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (cont.)

Herbicide	Rate of product per broadcast acre	Remarks
Postemergence		
Basagran (bentazon)	1.5 to 2 pt of 4S	Apply when weeds are small. Pea injury can occur. See label precautions.
Poast (sethoxydim)	1 to 1.5 pt of 1.5EC	Use crop-oil concentrate, 2 pt per acre.
Pursuit (imazethapyr)	2 fl oz of 2EC	Add nonionic surfactant. Crops must have at least 1 true leaf or crop injury may result. Do not apply if Treflan is used.
Thistrol (MCPB)	2 to 4 pt of 2EC	Apply when peas have developed 6 to 12 nodes and weeds are less than 3 inches tall.
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3 pt	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
PEPPER		
Preemergence		
Command (clomazone)	1 to 2 pt of 4EC	Use lower rates on light soil textures. Must be incorporated.
Dacthal (DCPA)	6 to 14 lb of 75WP	Apply 4 to 6 weeks after transplanting or when direct-seeded plants are 4 to 6 inches tall.
Devrinol (napropamide)	2 to 4 lb of 50WP	Can be applied to direct-seeded plants or transplants. Incorporate.
Treflan (trifluralin)	1 to 2 pt of 4EC or MTF	Incorporate. Apply to transplants only.
Postemergence		
Poast (sethoxydim)	1 to 1.5 pt of 1.5EC	Use crop-oil concentrate, 2 pt per acre. Maximum of 5 pt Poast per acre per season. 20 day preharvest interval.
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3 pt	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
POTATO		
Preemergence		
Dacthal (DCPA)	6 to 14 lb of 75WP	Apply at planting, drag off, or lay-by.
Dual (metolachlor)	1.5 to 3 pt of 8EC, or 6 to 12 lb of 25G	Apply preemerge, incorporated, or at lay-by. Do not use on muck soils.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (cont.)

Herbicide	Rate of product per broadcast acre	Remarks
Eptam (EPTC)	3.5 to 7 pt of 7EC	Incorporate immediately after applying. The variety Superior is sensitive.
Lexone or Sencor (metribuzin)	0.6 to 1.33 lb of 75DF	Make a single application prior to emergence.
Linex or Lorox (linuron)	1.5 to 2.5 pt of 4L, or 1 to 4 lb of 50WP or 50DF	Apply after planting but before potato emergence. Plant "seed" 2 inches deep.
Prowl (pendimethalin)	1.5 to 3 pt of 4EC	Incorporate lightly. Do not use on muck soils.
Treflan (trifluralin)	1 to 2 pt of 4EC or MTF	Apply after planting and incorporate uniformly.
Postemergence		
Lexone or Sencor (metribuzin)	0.5 to 1 pt of 4L, or 0.3 to 0.67 lb of 75DF	Do not use on smooth-skinned white or red-skinned potatoes. Apply only if 3 successive days of sun have occurred prior to application. Apply before weeds are 1 inch tall.
Poast (sethoxydim)	1 to 1.5 pt of 1.5EC	Use crop-oil concentrate, 2 pt per acre. Maximum of 5 pt Poast per acre per season. 20 day preharvest interval.
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
PUMPKIN AND SQUASH		
Preemergence		
Command (clomazone)	1.5 to 2 pt of 4EC	Pumpkins only. Requires incorporation. May cause some temporary bleaching of pumpkin plants.
Curbit (ethalfluralin)	3 to 4.5 pt of 3EC	Apply after seeding squash or pumpkins and before weed or crop emergence. Carefully read label before using.
Dacthal (DCPA)	6 to 14 lb of 75WP	Not effective on soils with greater than 5% organic matter. Use on summer and winter squash only. Apply when plants are well established and have 4 to 5 leaves.
Prefar (bensulide)	5 to 6 qt of 4EC	Incorporate or irrigate in. See label restrictions.
Postemergence		
Poast (sethoxydim)	1 to 1.5 pt of 1.5EC	Use crop-oil concentrate, 2 pt per acre. Maximum of 3 pt Poast per acre per season. 14 day preharvest interval.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (cont.)

Herbicide	Rate of product per broadcast acre	Remarks
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3 pt	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
SNAP BEANS OR GREEN BEANS		
Preemergence		
Dacthal (DCPA)	6 to 14 lb of 75WP	Not effective on soils with more than 5% organic matter. Do not feed treated plants to livestock.
Dual (metolachlor)	1.5 to 3 pt of 8EC	
Eptam (EPTC)	3.5 pt of 7EC	Do not use on flat-podded beans. Must be incorporated.
Treflan (trifluralin)	1 to 1.5 pt of 4EC or MTF	Must be incorporated.
Postemergence		
Basagran (bentazon)	1.5 to 2 pt of 4S	Apply when weeds are small. Beans are tolerant after the first trifoliate has fully expanded. Some injury to beans may occur.
Poast (sethoxydim)	1 to 2 pt of 1.5EC	Use crop-oil concentrate, 2 pt per acre. Maximum of 4 pt Poast per acre per season. 15 day preharvest interval.
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3 pt	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
TABLE BEET		
Preemergence		
Pyramin (pyrazon)	3 to 3.5 qt of 4.2FL	Rainfall or irrigation is needed for activation.
Ro-Neet (cycloate)	2 to 3 qt of 6EC	Must be incorporated. Use on mineral soils only.
Postemergence		
Pyramin (pyrazon)	3.5 qt of 4.2FL	Timing is very important. Treat when beets have 2 expanded leaves and weeds have 2 to 4 leaves.
Spin-aid (phenmedipham)	3 to 6 pt of 1.3E	Apply in 11 to 22 gal of water per acre. Apply to beets with at least 4 true leaves.

Table 4. Herbicide Rates and Guidelines for Use in Vegetable Crops (cont.)

Herbicide	Rate of product per broadcast acre	Remarks
Stale Seedbed		
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.
TOMATO		
Preemergence		
Dacthal (DCPA)	6 to 14 lb of 75WP	Apply when direct-seeded plants are established and 4 to 6 inches tall or when transplanted plants have been established for 4 to 6 weeks.
Devrinol (napropamide)	2 to 4 lb of 50DF	Must be incorporated.
Lexone or Sencor (metribuzin)	0.5 to 1 pt of 4L, or 0.33 to 0.66 lb of 75DF	Apply to transplanted tomatoes only. May be incorporated.
Prefar (bensulide)	4 to 5 qt of 4EC	Incorporate or irrigate in. Do not plant other than specified crops for 18 months after treatment.
Tillam (pebulate)	2.7 to 4 qt of 6EC	Do not use Tillam with row covers.
Treflan (trifluralin)	1 to 2 pt of 4EC or MTF	Must be incorporated. For direct-seeded plants apply at blocking or thinning as a directed spray between rows.
Postemergence		
Lexone or Sencor (metribuzin)	0.5 to 0.75 pt of 4L, or 0.33 to 0.67 lb of 75DF	Plants must be established; see label. Apply only if 3 successive days of sun have occurred prior to application.
Poast (sethoxydim)	1.0 to 2 pt of 1.5EC	Use crop-oil concentrate, 2 pt per acre. Maximum of 4.5 pt Poast per acre per season. 20 day preharvest interval.
Stale Seedbed		
Gramoxone Extra (paraquat)	2 to 3 pt	See discussion of reduced tillage systems.
Roundup (glyphosate)	1.5 to 3 qt	See discussion of reduced tillage systems.

Table 5. Weed Susceptibility to Herbicides Labeled for Use in Vegetable Crops

	Weeds controlled	
Herbicide	Grasses	Broadleaves
Alanap (naptalam)		carpetweed, chickweed, cocklebur, hairy galinsoga, lambsquarters, purslane, ragweed
Balan (benefin)	annual bluegrass, barnyardgrass, crabgrass, fall panicum, foxtail, goosegrass, seedling johnsongrass	carpetweed, chickweed, knotweed, lambsquarters, pigweed, purslane
Basagran (bentazon)		Canada thistle, purslane, lambsquarters, ragweed, galinsoga, jimsonweed, smartweed, velvetleaf, wild mustard, cocklebur
Bladex (cyanazine)	annual bluegrass, barnyardgrass, crabgrass, fall panicum, foxtail, goosegrass, witchgrass	carpetweed, cocklebur, chickweed, purslane, morningglory, jimsonweed, lambsquarters, nightshade, pigweed, ragweed, velvetleaf, wild mustard
Buctril (bromoxynil)		mustard, cocklebur, pennycress, jimsonweed, annual morningglory, nightshade, lambsquarters, smartweed, pigweed
Command (clomazone)	barnyardgrass, crabgrass, fall panicum, foxtail, goosegrass, seedling johnsongrass	purslane, ragweed, jimsonweed, lambsquarters, smartweed, velvetleaf
Curbit (ethalfluralin)	annual bluegrass, crabgrass, barnyardgrass, foxtail, goosegrass, fall panicum, seedling johnsongrass, shattercane, witchgrass	wild buckwheat, carpetweed, chickweed, lambsquarters, pigweed, nightshade, purslane
2,4-D amine		carpetweed, dandelion, dock, galinsoga, pigweed, jimsonweed, lambsquarters, morningglory, plantain, ragweed, smartweed, thistle, wild mustard
Dacthal (DCPA)	crabgrass, foxtail, barnyardgrass, goosegrass, annual bluegrass, seedling johnsongrass	carpetweed, lambsquarters, common chickweed, purslane
Devrinol (napropamide)	barnyardgrass, weedy brome, crabgrass, foxtail, goosegrass, seedling johnsongrass	chickweed, purslane, common groundsel, prostrate knotweed, lambsquarters, pigweed, prickly lettuce
Dual (metolachlor)	barnyardgrass, crabgrass, fall panicum, foxtail, goosegrass, witchgrass, yellow nutsedge	nightshade, carpetweed, galinsoga, pigweed
Eptam (EPTC)	annual bluegrass, crabgrass, barnyardgrass, foxtail, goosegrass, shattercane, witchgrass	annual morningglory, carpetweed, chickweed, lambsquarters, nightshade, purslane

Table 5. Weed Susceptibility to Herbicides Labeled for Use in Vegetable Crops (cont.)

	Weeds controlled	
Herbicide	Grasses	Broadleaves
Eradicane Extra (EPTC + safener + extender)	annual bluegrass, crabgrass, barnyardgrass, goosegrass, seedling johnsongrass, volunteer small grains, foxtail	annual morningglory, nightshade, carpetweed, lambsquarters, purslane, pigweed, velvetleaf
Fusilade 2000 (fluazifop-butyl)	bermudagrass, goosegrass, johnsongrass, wild proso millet, barnyardgrass, fall panicum, foxtail, crabgrass, witchgrass, volunteer cereals	
Goal (oxyfluorfen)		eveningprimrose, pigweed, common groundsel, purslane, black nightshade, shepherdspurse
Gramoxone Extra (paraquat)	most annual grasses and broadleaves	See discussion of reduced tillage systems.
Karmex, others (diuron)	barnyardgrass, crabgrass, annual bluegrass, foxtail	pigweed, purslane, ragweed, chickweed, mustard, pennycress, velvetleaf
Kerb (pronamide)	barnyardgrass, brome, annual bluegrass, panicum, foxtail, goosegrass, volunteer small grains	carpetweed, chickweed, henbit, knotweed, purslane, lambsquarters, nightshade, morningglory
Lasso, Stall (alachlor)	barnyardgrass, crabgrass, foxtail, goosegrass, fall panicum, witchgrass	carpetweed, pigweed, galinsoga, nightshade, purslane
Lexone or Sencor (metribuzin)	downy brome, crabgrass, foxtail, seedling johnsongrass	pigweed, purslane, ragweed, chickweed, jimsonweed, lambsquarters, pepperweed, shepherdspurse, smartweed, prickly sida
Linex or Lorox (linuron)	barnyardgrass, crabgrass, fall panicum, goosegrass	annual morningglory, carpetweed, groundsel, lambsquarters, mustard, cocklebur, pigweed, prickly sida, purslane, smartweed, velvetleaf
Poast (sethoxydim)	bermudagrass, goosegrass, johnsongrass, quackgrass, wild proso millet, barnyardgrass, fall panicum, foxtail, crabgrass, witchgrass, volunteer cereals	
Prefar (bensulide)	crabgrass, foxtail, fall panicum, goosegrass	

Table 5. Weed Susceptibility to Herbicides Labeled for Use in Vegetable Crops (cont.)

	Weeds controlled	
Herbicide	Grasses	Broadleaves
Prowl (pendimethalin)	barnyardgrass, crabgrass, fall panicum, foxtail	carpetweed, lambsquarters, pigweed, purslane
Pursuit (imazethapyr)		nightshade, pigweed, kochia wild mustard
Pyramin (pyrazon)		lambsquarters, pigweed, ragweed, shepherdspurse, purslane, nightshade, mustard, henbit, smartweed
Ro-Neet (cycloate)	annual bluegrass, crabgrass, volunteer barley, foxtail, barnyardgrass	nightshade, henbit, lambsquarters, purslane, redroot pigweed, shepherdspurse
Roundup (glyphosate)	most annual and perennial grasses and broadleaves; see discussion of reduced tillage systems	most annual and perennial grasses and broadleaves; see discussion of reduced tillage
Sinbar (terbacil)	crabgrass, foxtail, seedling johnsongrass, barnyardgrass, annual bluegrass	chickweed, lambsquarters, wild mustard, pepperweed, shepherdspurse, dandelion, knotweed, pigweed, purslane, plantain, ragweed, henbit, jimsonweed
Sutan+ (butylate + safener)	barnyardgrass, crabgrass, fall panicum, foxtail, goosegrass, shattercane, seedling johnsongrass	
Thistrol (MCPB)		Canada thistle, lambsquarters, pigweed, smartweed, sowthistle, annual morningglory
Tillam (pebulate)	barnyardgrass, crabgrass, foxtail, goosegrass	lambsquarters, pigweed, purslane, shepherdspurse
Treflan (trifluralin)	annual bluegrass, crabgrass, barnyardgrass, foxtail, seedling johnsongrass, goosegrass	carpetweed, chickweed, knotweed, lambsquarters, pigweed, purslane

Environmental and Health Hazards of Herbicides

Nontargeted effects can occur from the use of herbicides. With the increased attention directed toward nontargeted effects of pesticides, it is very important that you educate yourself about these effects and consider them when designing weed management systems. The following section discusses some of the potential environmental and health hazards of herbicides. This is only an overview. More detailed information is contained in the herbicide label, other chapters of this *Handbook*, and *Proceedings of the Illinois Specialty Growers Convention* (University of Illinois at Urbana-Champaign, Department of Horticulture).

Environmental Hazards

Adverse environmental effects from herbicides can have long-term consequences that are difficult to correct and must be avoided. Some environmental hazards, such as herbicide drift and carryover, will affect mainly your operation while other hazards, such as water contamination, affect all the residents of Illinois.

Table 6. Common Names and Corresponding Trade Names

Common name	Trade name	Common name	Trade name
alachlor	Lasso	glyphosate	Roundup
atrazine	AAtrex, others	imazethapyr	Pursuit
benefin	Balan	linuron	Linex, Lorox
bensulide	Prefar	MCPB	Thistrol
bentazon	Basagran	metolachlor	Dual
bromoxynil	Buctril	metribuzin	Lexone, Sencor
butylate + safener	Sutan +	napropamide	Devrinol
clomazone	Command	naptalam	Alanap
cyanazine	Bladex	oxyfluorfen	Goal
cycloate	Ro-Neet	paraquat	Gramoxone Extra
2,4-D amine	several names	pebulate	Tillam
DCPA	Dacthal	pendimethalin	Prowl
diuron	Karmex, others	phenmedipham	Spin-aid
EPTC	Eptam	pronamide	Kerb
EPTC + safener + extender	Eradicane Extra	pyrazon	Pyramin
		sethoxydim	Poast
ethalfluralin	Curbit	terbacil	Sinbar
fluazifop-butyl	Fusilade	trifluralin	Treflan

The following section discusses some of the potential hazards and methods to avoid them.

Herbicide Carryover

Herbicide carryover from persistent herbicides has been a particular problem to growers of vegetable crops. Persistence is dependent on herbicide characteristics (method of degradation, water solubility, and rate of application) and site characteristics (soil type, rainfall, and temperature). Avoid carryover because correction of carryover problems once they occur is virtually impossible. The most important method used to avoid herbicide carryover is to follow label rotation restrictions. Consider label restrictions as minimum guidelines. Table 7 summarizes some of the label restrictions. Always refer to the label for specific information. If differences between the table and herbicide label occur, always follow label information. Further information on avoiding vegetable crop injury from herbicide carryover is also contained in recent editions of the *Proceedings of the Illinois Specialty Growers Convention* (University of Illinois at Urbana-Champaign).

Herbicide Drift

Another frequent hazard to vegetable growers is crop injury from herbicide drift. Certain herbicides, if not used correctly, can cause injury to nontarget plants. Herbicides such as **clomazone (Command), dicamba,** and **2,4-D** can drift up to a mile and cause serious damage to grapes, tomatoes, peppers, other vegetables, fruit trees, and ornamental plants. Before spraying clomazone, dicamba, or 2,4-D, survey the area for desirable plants. Spray only on calm days and use drift inhibitors when appropriate. Minimize drift by applying herbicides with nozzles that produce large droplets. Use an amine formulation of 2,4-D to reduce vapor drift. Spray clomazone, dicamba, and 2,4-D when the temperature is expected to be lower than 80° to 85°F for several days after treatment. Avoid applying clomazone to wet soils and incorporate it soon after application.

Spray Tank Residuals

Dicamba or 2,4-D residues in spray tanks can also injure susceptible vegetable crops. Carefully follow label directions for cleaning spray equipment after using dicamba or 2,4-D. If possible, do not use the same spray equipment to apply 2,4-D or dicamba that you use to apply other pesticides.

Herbicide Resistance

There are now more than 50 documented reports worldwide of weeds developing resistance to herbicides. Herbicide resistance tends to occur when a persistent herbicide is used year after year in the same field. Thus, continued use of the same herbicide on a perennial crop such as asparagus should be avoided. Many of the resistance problems have occurred with triazine herbicides such as simazine and atrazine. The labels of those herbicides contain information about avoiding resistance problems.

Approaches to avoid herbicide resistance combine herbicides and mechanical (cultivation) and cultural (crop rotation) weed management practices. Rotate between or use tank mixes of herbicides with different mechanisms of killing the plant. For example, in asparagus rotate between Sencor and Treflan. Use tillage to control weeds that escape from herbicide applications. Especially important in minimizing any weed resistance that does occur is to scout your fields, paying special attention to any patches of a weed normally controlled by the herbicide.

Water Quality

Residues of some herbicides such as atrazine, metolachlor, alachlor, cyanazine, and metribuzin have been found in surface water or groundwater. The levels detected have normally been low, but contamination of water resources is a growing concern. For example, groundwater contamination from pesticides and nitrates is a particular concern in areas of the state with sandy soils and shallow groundwater.

Factors determining the potential for groundwater and surface water contamination include herbicide solubility in water, rate of degradation, volatility, and tendency for the herbicide to attach to soil particles or organic matter. Herbicides that have high water solubility and long persistence are a particular concern.

Site characteristics (soil type, soil depth, water table depth, slope, and weather) also can lead to contamination of water resources from herbicides. You should be aware of the potential problem of herbicide contamination and take all possible steps to avoid contamination of surface and subsurface water resources.

Disposing of Herbicides and Containers

Surplus Herbicides

If possible, use surplus herbicide mixtures by applying them to labeled crops that have the same weed problems. Never drain surplus pesticides in any location where they can contaminate ground or surface water supplies. Avoid creating surplus tank mixes by accurately measuring the treatment area and mixing the correct amount of pesticide. If a large amount of surplus pesticide is generated, contact the Illinois EPA Division of Land Pollution Control for instructions about disposal.

Pesticide Containers

Rinse all empty containers, regardless of their type, three times before disposal. Dump rinse water into the tank. Puncture or break triple-rinsed containers to facilitate drainage and to prevent reuse for any purpose. Then dispose of containers according to label directions and local regulations, with regard for the protection of water resources.

Health Hazards

Health hazards from exposure to pesticides can be divided into acute or chronic effects according to the duration and amount of exposure.

Acute Effects

Acute effects or poisoning occur soon after exposure to large amounts of a pesticide. These types of effects are dangerous to you, your family, and your workers. The potential for human or animal poisoning from pesticides can be reduced by carefully storing and handling pesticides. Keep pesticides in a separate area, room, or building used only for storage purposes. The storage area should be dry and ventilated. Keep all entrances to the area locked at all times to protect children, other people, and animals. CAUTION: Do not store herbicides together with insecticides. Remove only the pesticide that will be used in one day, and after use return the pesticide to the storage area. Follow label directions when handling pesticides. Pay particular attention to sections on protective clothing requirements and any field reentry limitations.

Herbicide Residues in Vegetables

The issue of pesticide residues in vegetables is currently receiving intense public attention. Many of the herbicides used in vegetable crops are older products that were registered before current toxicological and environmental standards were established by the USEPA. Congress has required the USEPA to reregister these older products to bring the data up to current toxicological and environmental standards. This reregistration has caused some companies to remove products from the market.

Data exist that some herbicides (and other pesticides) can potentially cause adverse health effects, such as cancer from chronic (long-term) exposure.

Table 7. Label Restrictions (in Months) on Rotating to Vegetable Crops

Herbicide	Tomato	Pea	Snap bean	Sweet corn	Pumpkin	Melon	Cole crops
Soybean herbicides							
Canopy	18[c]	FB[a]	FB	FB	FB	FB	FB
Classic	15[c]	FB	FB	FB	FB	FB	FB
Command	NNY	AT	9	9	AT	9	NNY
Commence	NNY	9	9	9	9	9	NNY
Dual	18	AT	AT	AT	18	18	18
Lexone or Sencor	4–10	4–10	12	12	12	12	12
Lorox	NNY	NNY	NNY	4	NNY	NNY	NNY
New Lorox Plus	FB	FB	FB	FB	FB	FB	FB
Preview	10	FB	FB	FB	FB	FB	FB
Prowl	NY	NY	NY	AT[b]	NY	NY	NY
Pursuit	18	AT	4	18	18	18	18
Reflex	18	18	18	10	18	18	18
Salute	4	8	12	4	12	12	12
Scepter	18	18	11	18	18	18	18
Squadron	18	18	11	18	18	18	18
Tri-Scept	18	18	11	18	18	18	18
Tornado	18	18	18	10	18	18	18
Treflan	AT[c]	AT	AT	5	5	5	AT
Turbo	12	8	8	12	8	12	12
Corn herbicides							
AAtrex and others	NNY	NNY	NNY	AT	NNY	NNY	NNY
Bicep	18	18	18	AT	18	18	18
Bladex	NY	NY	NY	AT	NY	NY	NY
Conquest	18	18	18	AT	18	18	18
Lariat	NNY	NNY	NNY	AT	NNY	NNY	NNY
Princep	NNY	NNY	NNY	AT	NNY	NNY	NNY
Prozine	NNY	NNY	NNY	AT	NNY	NNY	NNY
Sutazine	18	18	18	AT	18	18	18

AT = herbicide labeled for the crop or no rotation restriction exists; NY = the crop can be planted the year after application; NNY = the crop cannot be planted the following year; and FB = a field bioassay required before planting the crop.
[a]The rotation restrictions are in months after application.
[b]Sweet corn for processing only.
[c]Transplanted tomatoes only.

There is controversy about the reliability and importance of this data. Groups that are particularly concerned about pesticide residues in vegetables include the National Resource Defense Council, National Coalition Against Misuse of Pesticides, and Americans for Safe Food. Because customers will question you, it is recommended that you stay up-to-date on this issue. The above groups have information reflecting their views. Information reflecting food industry views is also available from such groups as The Alliance for Food and Fiber, Food Marketing Institute, and Center for Produce Quality. Recent editions of the *Proceedings of Illinois Specialty Growers Convention* also have articles on pesticide residues in vegetables.

12 Plant Disease Management for Commercial Vegetable Crops

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The successful control of vegetable diseases requires an integrated program that includes the use of resistant varieties, crop rotation, balanced soil fertility, weed and insect control, and proper crop culture as well as the proper selection and timing and method of application of fungicides, bactericides, or nematicides. Economical control depends on establishing an overall disease management system for the entire farm. Keeping careful records of the crops that have been planted, the problems encountered, and the pesticides used is important.

Because many disease problems originate with seeds or transplants, growers should follow the seed-treatment recommendations given in this chapter and in *Report on Plant Diseases* No. 915, "Vegetable Seed Treatment," or be sure to obtain planting material that is certified as disease-free.

This chapter lists the registered fungicides and application intervals for various vegetable crops as approved by the Food and Drug Administration (FDA) and the U.S. Environmental Protection Agency (USEPA) as of September 1, 1992, to the best of our knowledge. Tables 1 and 2 give the number of days between the last application at the normal rate and harvest as well as other restrictions that will keep residues within the tolerances set by the FDA. Refer to current labels for information on rates, timing, and methods of application, as well as for information on follow-up crops and other restrictions.

The listing of a chemical as approved for use on a particular crop does not mean that the Illinois Cooperative Extension Service or Agricultural Experiment Station recommends the use of the chemical for that crop. Our specific recommendations for disease control are given in Table 3.

In some instances, a tolerance has been set but a definite interval has not been established. The absence of an interval for a particular crop in the listings does not necessarily mean that the fungicide may not be used on that crop. To ensure that the crop produced does not exceed the tolerance, the use of the fungicide would require a restriction such as "Do not apply after first blooms appear" or "Do not apply after edible parts form." This information appears on the product label.

In a few cases the interval and dosage have been established, but the allowable residue concentration has not been determined. Again, this does not mean that the fungicide may not be used on the crops for which it is labeled. It does mean, however, that until the tolerance is established, it must be considered as zero. These cases are reviewed each year, and some are cancelled when the chemical manufacturer supplies the EPA with additional data.

Growers must follow a program of disease control that will assure that the vegetables produced do not contain excessive fungicide residues. Vegetables marketed with residues exceeding the FDA tolerances may be injurious to consumers, may be confiscated, and may subject the grower to legal action.

Growers have nothing to fear from the law as long as they use fungicides and other pesticides according to the current label and only on the crops specified, in the amounts specified, and at the times specified. The prudent grower keeps a record of the products and trade names used, the percentage of active ingredients, dilutions, rates of application per acre, and dates of application.

General Suggestions on Fungicide Application

We recommend that the following practices be used when applying fungicides.

• Cover the foliage uniformly. *Ground equipment*—Apply 75 to 125 gallons per acre at 100 to

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

400 pounds per square inch of pressure. Lowering volumes and/or pressures may provide adequate coverage, but high-volume, high-pressure applications provide ideal coverage. Make sure the sprayer is functioning properly. Check the nozzles for cleanliness and wear. Boom height, accuracy of pressure gauge, agitation, and calibration should also be checked. *Aerial application*—Apply recommended amounts of pesticide per acre in 3 to 5 gallons of water. Make sure nozzles are properly aligned and clean, so uniform application is achieved. Cover a swath no wider than is reasonable for the aircraft and boom being used. Spray only those fields that are suitable for aerial application. Avoid fields of irregular shape or topography, particularly if they are bounded by power lines, trees, or other obstructions.

- Whenever possible, spray when the air is still or when wind velocity is not excessive (less than 10 mph).
- Avoid situations where pesticide drift may cause needless problems.
- When it is compatible with the product label, use a spray adjuvant (surfactant). Some commonly available surfactants are: Kalo: Bio 88, Bio-Film, and Regulaid (for systemic fungicides); Hopkins: Plyac; Rohm & Haas: Triton AG-98, B-1956, CS-7; Ortho: Chevron Spray Sticker, Chevron Spreader, X-77 Spreader; Miller: NuFilm P, NuFilm 17; DuPont: Spreader Sticker. Spray adjuvants are most useful on cabbage, cauliflower, Brussels sprout, onions, and peppers.

General Suggestions on Soil Fumigation

Follow the manufacturer's directions exactly. Fumigants work best in light, loose soils that are free of trash, clods, and lumps. Avoid recontaminating treated soil. It is best to apply fumigants during the fall before planting. In general, the soil temperature must be at least 55° to 60°F at the 6 inch depth, with a time lapse of 21 to 28 days between treating and seeding. Some require gas-tight plastic covers. Many fumigants are restricted-use chemicals.

General Suggestions for Use of Nematicides

Use nematicides only where soil analysis shows a nematode problem to be present. Follow soil sampling instructions in *Report on Plant Diseases* No. 1100, "Collecting and Submitting Soil Samples for Nematode Analysis." Both RPD No. 915 and No. 1100 are available for 50 cents each from Extension Plant Pathology, N-533 Turner Hall, 1102 South Goodwin Avenue, Urbana, IL 61801. Checks should be made out to the University of Illinois.

Table 1. Limitations on Days Between Application and Harvest and Other Restrictions When Using Fungicides on Vegetables in Illinois

Crop	Benlate[a]	Bravo[b]	Maneb[c]	Mancozeb[d]	Botran[f]
Asparagus	..	..	..	A; root dip	..
Beans (dry, lima, snap)	14, 28 on lima, B,	7, (snap only) B; (lima, dry)	30 (dry only)	..	2, B
Beet, garden	..	..	..	..	..
Broccoli	..	0	7	..	..
Brussels sprout	..	0	7	..	..
Cabbage	..	0	7	..	..
Cantaloupe (muskmelon and honeydew melon)	0	0	5	5	..
Carrot	..	0	..	..	ph
Cauliflower	..	0	7	..	..
Celery	7	7	..	..	..
Chinese cabbage	..	7	7	..	..
Corn, sweet and pop	..	14, B[e]	7, B	7, B	..
Cucumber	0	0	5	5	0

Table 1. Limitations on Days Between Application and Harvest and Other Restrictions When Using Fungicides on Vegetables in Illinois (cont.)

Crop	Benlate[a]	Bravo[b]	Maneb[c]	Mancozeb[d]	Botran[f]
Eggplant	..	..	5	..	..
Endive, escarole	..	..	10	..	14
Fennel	..	..	..	14	..
Garlic	..	7	..	..	pp, ph
Kale	..	..	10	..	..
Kohlrabi	..	..	10	..	..
Leek	..	14	..	..	..
Lettuce	..	..	10	..	14
Mustard greens	..	..	..	..	..
Onion	..	green, 14; dry, 7	7, D, pb	7, D, pb	pp, ph
Parsley	..	..	..	..	..
Parsnip	..	10,B	..	..	..
Peas	..	..	..	..	..
Pepper	..	..	7	..	..
Potato, Irish	..	0	14, C	14, C	14, B
Pumpkin	0	0	5	..	..
Radish	..	..	..	..	..
Shallots	..	14	..	..	..
Spinach	..	..	..	..	..
Squash	0	0	5	5 (summer only)	..
Tomato	0	0	5	5	0
Turnip, rutabaga	..	..	..	..	..
Watermelon	0	0	5	5	..

Numbers in the table indicate number of days between last application and harvest; 0 = up to harvest. Dots in a column indicate that the fungicide is not registered for use on that particular vegetable. Other abbreviations used in the table are as follows:

A = Postharvest application to ferns only or to young plantings that will not be harvested; B = do not feed treated tops or forage to livestock; C = do not use treated seed or seed pieces for feed or food; D = do not apply to exposed bulbs; pb = plant bed treatment; ph = postharvest spray or dip; pp = preplant soil treatment.

[a]Do not apply Benlate alone; always use in combination with mancozeb or other labelled protective fungicide such as Captan, Bravo, Dyrene, or maneb. Do not mix with Mertect or Topsin-M.

[b]Chlorothanonil is sold as Bravo W75, 500, 720, and 90DG. It is also sold in combination with metalaxyl as Ridomil/Bravo 81W and with copper and maneb as Bravo C/M.

[c]Maneb is sold as Maneb 80 and Maneb Plus Zinc F4.

[d]Mancozeb is sold as Dithane F-45, Dithane M-45, Dithane DF, Manzate 200 DF, and Penncozeb.

[e]Do not apply if the crop will be used for processing.

[f]Dichloran is sold as Botran 75W.

Table 2. Label Information on Fungicides and Nematicides of Less General Use

Fungicide	Crops and use restrictions
Aldicarb	
Temik 15G	For nematode control. **Beans (dry), sweet potato.**
Carbofuran	
Furadan 15G	**Corn** (sweet and pop): For nematode control. Apply in band or furrow at planting. **Cucumber, melons, squash, pumpkin**—incorporate into top 3 inches of soil.
Copper fungicides[b]	
tribasic copper sulfate (many trade names)	**Beans, beet, broccoli, Brussels sprout, cabbage, cantaloupe, carrot, cauliflower, celery, cucumber, eggplant, honeydew melon, lettuce, muskmelon, onion, pea, pepper, potato, pumpkin, radish, spinach, squash, tomato, watermelon.**
copper sulfate (many)	**Beans, broccoli, cabbage, cantaloupe, cassaba melon, cauliflower, celery, cucumber, honeydew melon, muskmelon, Persian melon, potato, pumpkin, radish, squash, tomato, watermelon.**
Copper ammonium carbonate (Copper-Count N)	**Beans, cabbage, cantaloupe, carrot, cassaba melon, celery, crenshaw melon, cucumber, honeydew melon, lettuce, muskmelon, pepper, Persian melon, potato, squash, tomato, watermelon.**
copper hydroxide (Champion, Kocide 101 and 606)	**Beans, broccoli, Brussels sprout, cabbage, cantaloupe, carrot, cauliflower, celery, cucumber, eggplant, lettuce, muskmelon, onion, pea, pepper, potato, pumpkin, squash, tomato, watermelon.**
copper oxychloride sulfate (COCS, Copro 50, CS-56, Coxysul)	**Beans, beet, broccoli, Brussels sprout, cabbage, cantaloupe, carrot, cassaba melon, cauliflower, celery, crenshaw melon, cucumber, eggplant, honeydew melon, lettuce, muskmelon, onion, pea, Persian melon, potato, pumpkin, spinach, squash, tomato, watermelon.**
bordeaux mixture (many trade names)	**Asparagus, beans, beet, broccoli, Brussels sprout, cabbage, carrot, cassaba melon, celery, collard, crenshaw melon, cress, cucumber, eggplant, honeydew melon, horseradish, kale, muskmelon, mustard, pepper, Persian melon, potato, pumpkin, radish, rape, rutabaga, spinach, squash, tomato, turnip, watermelon.**
Ethoprop	
(Mocap)	For nematode control. **Beans** (snap and lima), **cabbage, corn** (sweet), **cucumber, potato, sweet potato.**
Fenamiphos	
(Nemacur 15G)	For nematode control. **Brussels sprout, cabbage, eggplant, garlic, and okra.**
Fosetyl-AL	
(Aliette)	**Asparagus**: spear slime and Phytophthora crown rot, 110 days[a];

Table 2. Label Information on Fungicides and Nematicides of Less General Use (cont.)

Fungicide	Crops and use restrictions
Fosetyl-AL (cont.)	**Broccoli, Brussels sprouts, cabbage, Chinese broccoli, bok choy, Napa cabbage, Chinese mustard, cauliflower, collards, kale, kohlrabi, mustard greens, rape greens**: downy mildew, 3 days[a]; **Leafy vegetables**: downy mildew, 3 days[a]; **Onion** (dry bulb): downy mildew, 7 days[a].
Iprodione[d] (Rovral)	**Beans**[c]: Sclerotinia. **Broccoli**: blackleg. **Carrot**: Alternaria leaf spot, no more than 8 applications. **Garlic**: white rot. **Lettuce**: lettuce drop and bottom rot, no more than 3 treatments, 14 days[a]. **Onion** (dry): Botrytis and Alternaria purple blotch, 7 days[a]. **Potatoes**: early blight and white mold, 14 days[a]. The following crops may be rotated after harvest: **garlic, dry bulb onions, broccoli, lettuce, peanuts, carrots, beans,** and **potatoes.** The following crops may be rotated one month following the last iprodione application: **root crops, tomatoes,** and **cotton.**
Metalaxyl (Apron 25WP)	Seed treatment for control of Pythium and Phytophthora damping-off and root rot on **beans, beet, pea, lentils, okra,** and **edible soybeans.**
(Ridomil 2E)	*Bedding plants* to control Pythium damping-off: **Asparagus, broccoli, cabbage, cauliflower, cucurbits, legumes, lettuce, onion, spinach, squash,** and **tomatoes.** Apply 2-4 pints per acre as preplant broadcast in 50 gal of water (1-2 fl oz or 2-4 tablespoons per 150 sq yd of bed in 2 gal of water) before or at the time of seeding to the surface of the beds and lightly incorporate or follow with one-half inch sprinkler irrigation water. Do not use for disease control in greenhouse crops. Do not dip plants in solutions containing Ridomil 2E, or crop injury may occur. *(Field use).* **Asparagus**: Phytophthora crown and spear rot. **Beans** (all), **lentils, pea, soybeans** (edible): Pythium damping-off and root rot when used at 1 pint per 13,000 linear feet of row, either in-furrow or in a 7-inch band at planting. **Broccoli, cabbage, cauliflower**: Pythium damping-off and Phytophthora basal stem rot. Applications may be broadcast using 4 pints per acre, applied at planting in 20-50 gal of water, or at 4-8 pints per acre, incorporated into the upper 2 inches. Seven-inch band applications at 2 pints per 13,000 linear feet of row are also labeled. **Cucurbit vegetables**: Pythium damping-off and cottony leak. Applications can be in a 7-inch band over the row at planting or at 4-8 pints per acre broadcast, using 20-50 gal of water. Broadcast applications may be incorporated to the 2-inch depth. **Onions, lettuce** (head), **spinach**: Pythium damping-off. Apply either broadcast or banded at planting. Follow label directions. **Pepper, eggplant**: Pythium damping-off, Phytophthora crown rot, 7 days[a].

Table 2. Label Information on Fungicides and Nematicides of Less General Use (cont.)

Fungicide	Crops and use restrictions
(Ridomil 2E) (cont.)	**Tomatoes**: Pythium damping-off, 7 days[a]. Apply either broadcast or banded immediately before or after planting in 20-50 gal of water. Pythium and Phytophthora fruit and root rots. Incorporate with irrigation.
(Ridomil 5G)	**Head lettuce**: Pythium damping-off. Preplant incorporated or preemergence applications. **Tomatoes**: Pythium damping-off. Pythium and Phythophthora fruit and root rots, 7 days[a].
(Ridomil/Bravo 81)	**Broccoli, cabbage, cauliflower**: downy mildew and Alternaria leaf spot, 7 days[a]; **Cucumber, melons, squash**: downy mildew, anthracnose, Cercospora leaf spot, gummy stem blight, leaf blight and scab; **Onions**[d] (dry bulb, seed and green): downy mildew, Botrytis leaf blight (blast) and purple blotch; dry, 7 days and green, 21 days[a]; **Potato**: late blight, tuber and storage rots (Pythium or Phytophthora), early blight and Botrytis vine rot, 7 days[a]; **Tomato**: late blight, early blight, anthracnose, and gray leaf spot, 7 days[a].
(Ridomil MZ58)	**Cucumbers, melons,** and **summer squash**: downy mildew, 5 days[a]; **Onion** (dry, seed): 7 days[a]; **Potato**: late blight, other Pythium or Phytophthora diseases, 14 days[a]; **Tomato**: late blight, 5 days[a].
(Ridomil PC 11G)	**Beans** (dry and green)[c]: Damping-off and seedling rots caused by Pythium and Rhizoctonia. Apply 12 oz per 1,000 feet of row at planting time.
Oxamyl (Vydate L)	**Carrots, cucurbits, eggplant, pepper, potato, sweet potato**: For nematode control. Apply before or at planting. Apply in transplant water for pepper or as foliar spray for peppers and vine crops 7 days.
PCNB (Terraclor)	**Beans**: base of plants *before* blossoming, soil and seed treatment at planting, or foliar spray. Do not feed treated bean vines to livestock. Do *not* apply after first bloom. **Broccoli, Brussels sprout, cabbage, cauliflower**: transplant solution (3/4 pint per plant) or row treatment before transplanting. **Pepper, tomato**: soil treatment at or before planting. **Tomato** (greenhouse): transplant solution (1/2 pt of 0.2% per plant). **Garlic**: soil and seed treatment at planting.
Streptomycin (Agri-Strep, Agrimycin 17, Streptomycin 17)	**Pepper, tomato**: plant beds only (200 ppm spray); **Potato**: seedpiece treatment only (100 ppm dip or dust). Soak cut seed pieces less than 30 min. Do not use treated seed for food or feed.

Table 2. Label Information on Fungicides and Nematicides of Less General Use (cont.)

Fungicide	Crops and use restrictions
Sulfur	Exempt when used with good agricultural practices. See label.
Terbufos (Counter 15G)	**Corn** (sweet and pop): apply in band or furrow at planting.
Thiabendazole (Mertect 340F)	**Carrot**: storage rot control. **Sweet potato**: "seed" root treatment. Do not use treated pieces for food or feed. **Potato**: seedpiece treatment and storage rot control.
Thiophanate methyl (Topsin-M70W, Topsin M4.5F)	**Beans**: white mold and gray mold. Snap or dry beans, 14 days; lima, 28 days. **Celery**: early and late blight, 7 days. **Cucurbits**: 0 days. **Onion**: apply in furrow at planting.
(TOPS 2.5D)	**Potato**: seedpiece treatment.
Thiram	**Onion**: furrow treatment. **Tomato**: 0 days, for leaf spots and fruit rots. Seed treatment: **Beans, beet, broccoli, Brussels sprout, cabbage, cantaloupe, carrot, cauliflower, collard, corn, cucumber, eggplant, endive, kale, kohlrabi, lettuce, lentils, mustard, okra, onion** (bulb, seed, and set), **pea, pepper, pumpkin, radish, spinach, squash, Swiss chard, tomato, turnip, watermelon.** WARNING: Do not use treated seed for food, feed, or oil for 7 days.
Triadimefon (Bayleton, 50% WP)	All **Cucurbits**: powdery mildew. May apply a maximum of 1 lb/A/yr.
Triphenyltin (Du-Ter, Super-Tin 4L)	**Carrot**[c]: Alternaria leaf spot and late blight, 14 days[a]. **Potato**: early and late blight, 7 days[a]. May be applied through irrigation systems (solid set or center pivot only).
Vinclozolin (Ronalin)	**Lettuce** (head or leaf): Sclerotinia drop, 28 days[a]. No more than 6 lb/A/season. **Onion** (dry): white rot, Botrytis blight, neck rot, 18 days[a]. No more than 10 lb/A/season.

[a]Number of days between last application and harvest.
[b]There are many other copper materials, but these are most widely available and labeled for use on vegetable crops. Exempt from tolerance if used with good agricultural practices; not exempt if used at the time of harvest or after harvest. See label.
[c]Do not feed treated tops or forage to livestock.
[d]Phytotoxicity to crop or followup crop. See label.

Table 3. Condensed Recommendations on Disease Management for Diseases of Commercial Vegetable Crops for 1993

Vegetable	Disease management practices
Asparagus	
Crown or root rots, Seedling blights, and wilt	No resistant varieties are available for control of these diseases. Treating the crowns with mancozeb may aid in control. Phytophthora can be controlled using Ridomil 2E applied over the bed. These diseases are best managed by good asparagus culture. Provide optimal soil fertility, and weed, insect, and rust control. Avoid excessive cutting. Avoid acidic (low pH) and poorly drained soils.
Rust, Cercospora and other leaf and branchlet blights	Grow rust-resistant varieties. Apply mancozeb to nonharvested fields up to August 15 and to harvested fields after harvest only. Applications should be made at 7- to 10-day intervals. Control is needed in 1- and 2-year beds, even with resistant varieties.
Beans (snap, dry, wax, and lima)	
Most diseases	When possible, use rotations of 2 to 3 years or longer between bean crops. Strict sanitation.
Seed decay, damping-off, seedborne stem blights, and root rots	Plant only western-grown, certified seed in a seed bed that is warm (60°-65°), well-prepared and well-drained. Treat seed with Apron 25WP plus thiram or captan and an insecticide. In-furrow sprays of Ridomil (2E or PC 11G) or seed treatment with Apron 25WP may be helpful for early season root-rot control. PCNB can be used to help control Rhizoctonia.
Root rots	Pythium root rot can be controlled using Ridomil (2E or PC 11G) as a band or furrow treatment at planting. Maintain optimal soil fertility. Utilize rotations of at least 2 to 3 years with other crops.
Bacterial blights	Plant only western-grown, certified seed. Utilize crop rotations of 2 to 3 years. Avoid cultivating when beans are wet. Field applications of 2 to 4 pounds of fixed copper (e.g., Kocide 101) per acre will provide good control of brown spot and halo blight, but only moderate control of common or fuscous blight. Do *not* use copper on fresh market lima beans.
Rust, anthracnose, and other fungal leaf, pod, and stem diseases	Utilize crop rotations of 2 to 3 years. Apply Bravo at 7- to 10-day intervals starting when disease first appears. Rust-resistant varieties are available for some types of beans. Sulfur can also be used but may be phytotoxic at high temperatures.
Gray mold	Apply Bravo, Benlate, Topsin-M, or Rovral at 25% bloom and repeat at full bloom. Thorough coverage of blossoms is essential.
White mold	Apply Botran (snap beans only), Benlate, Rovral, or Topsin-M at 25% bloom, and repeat at full bloom.
Mosaic virus diseases	Plant varieties with resistance to bean common mosaic, NY15 strain of common mosaic, and bean yellow mosaic. Avoid planting near clovers, birdsfoot trefoil, gladiolus, etc.
Soybean cyst nematode	Rotate at least 2 to 3 years with corn, small grains, alfalfa, or other nonhost crop. Do *not* include soybeans in the rotation. Temik may be used on dry beans.

Table 3. Condensed Recommendations on Disease Management for Diseases of Commercial Vegetable Crops for 1993 (cont.)

Vegetable	Disease management practices
Root-knot and lesion nematodes	Apply Temik (dry beans only) or Mocap (snap or lima beans) at planting.
Beet (garden), Swiss Chard	
Seed rot, damping-off, and seedborne leaf spot	Sow in a well-prepared seed bed. Treat seed with captan, thiram, or Apron (for Pythium). Make sure boron levels are adequate. Several soluble-boron formulations are available.
Cercospora leaf spot	Apply fixed copper weekly at the first sign of disease. Separate new from old plantings.
Carrots, Parsnips	
Seed rot, damping-off	Treat seed with captan or thiram. Plant in well-drained seed bed. Avoid overwatering.
Cercospora leaf spot, Alternaria leaf blight	Apply Bravo, Rovral, or Du-Ter, on 7 to 10 day intervals. Start when disease first threatens and repeat as needed.
White mold	Use a crop rotation of 3 to 4 years.
Aster yellows	Use insecticides to control leafhoppers that transmit the mycoplasma. Excellent early season leafhopper control is essential. Control must occur *before* leafhoppers feed.
Root-knot nematode	Fumigate mineral soils with Telone II, Vapam, or Vorlex, or practice a 3-year rotation with corn or other nonhost crops. Control broadleaf weed hosts. Vydate L (carrot only) may be applied at planting in furrow or broadcast 1 week prior to planting.
Parsnip canker, leaf spot, mildew	Spray with fixed copper 3 times at 10-day intervals at first sign of disease. Ridge soil over the shoulders to prevent canker infections.
Celery, Parsley	
Seed rot, damping-off, and seed-borne leaf blights	Treat seed with hot water, then captan or thiram. If damping-off starts, spray 2 to 3 times, 5 to 7 days apart with Bravo (celery only) or fixed copper. Seed 2 to 3 years old is free of late blight.
Leaf blights and spots (celery only)	Spray Benlate, Topsin-M, Bravo at 7 to 10 day intervals.
Aster yellows and Root-knot nematode	(See the section on Carrots and Parsnips)
Corn (sweet and pop)	
Seed rot, seedling blights, and seed-borne diseases	Plant seed treated with captan or thiram plus an insecticide. Plant shallow in warm, well-drained soil.
Goss' bacterial wilt	Use 2- to 3-year crop rotations when using susceptible corn (dent or sweet) varieties.
Stewart's disease	Plant resistant varieties or control corn flea beetles on young plants with an insecticide.

Table 3. Condensed Recommendations on Disease Management for Diseases of Commercial Vegetable Crops for 1993 (cont.)

Vegetable	Disease management practices
Smut	Plant tolerant varieties. Control corn borers as first tassels appear.
Maize dwarf mosaic, chlorotic dwarf, and wheat streak mosaic	Control johnsongrass and volunteer wheat. Plant wheat after the fly-free date. Some varieties tolerate maize dwarf better than others, but none are highly resistant.
"Helminthosporium" leaf blights, and anthracnose leaf blight	Plant resistant varieties. Spray Bravo, mancozeb, or maneb when disease first appears. Crop rotation and clean tillage will help reduce disease risk.
Rusts	Plant resistant varieties. Spray as for "Helminthosporium" blights.
Nematodes	Apply Furadan, Counter, or Mocap (sweet corn only) at planting time.
Crucifer crops (broccoli, Brussels sprout, cauliflower, cabbage, Chinese cabbage, collard, kale, kohlrabi, mustard, radish, rutabaga)	
Seed rot, damping-off, black rot, blackleg, Alternaria leaf spot	Sow only western-grown, hot-water-treated seed. Seed also should be treated with thiram or captan. Place seed beds where no crucifer has grown for 4 years or more and where water will not drain from fields recently planted to crucifers. Ridomil 2E applied at planting time will control Pythium damping-off and Phytophthora basal stem rot.
Wirestem (*Rhizoctonia*)	Incorporate PCNB-captan in upper 3 inches of soil before planting or drench after planting.
Clubroot	Use only healthy transplants. Avoid soils with a history of clubroot. If clubroot is present, adjust soil pH to 7.2 with hydrated lime. Rotate out of cruciferous crops for 7 years. Apply PCNB (Terraclor 75WP) in transplant water; use 3/4 pint per plant.
Black rot and blackleg	Use a crop rotation of 4 years or more. Use only hot-water-treated seed. Use care in the selection of plant bed sites. Be sure no drainage occurs to seed bed from old plantings. Control wild mustard and other cruciferous weeds. Purchase only certified, disease-free transplants. Do not dip transplants before planting. Sprays of fixed copper may help control black rot. Rovral can be used to control blackleg on broccoli. Bravo applied to control downy mildew may also help control blackleg. Some cabbage varieties resistant to black rot are available. Losses are generally lower where direct seeding is used.
Downy mildew, Alternaria leaf spot, and other fungal leaf diseases	Rotate with noncruciferous crops and use disease-free seed or transplants. Apply Bravo, Ridomil/Bravo 81W or maneb at weekly intervals. Start applications in seedbed or when plants are young. Ridomil and Aliette can be used to control downy mildew on some cruciferous crops.

Table 3. Condensed Recommendations on Disease Management for Diseases of Commercial Vegetable Crops for 1993 (cont.)

Vegetable	Disease management practices
Internal tipburn	Plant resistant varieties. Avoid overfertilizing, especially with nitrogen.
Fusarium yellows	Plant only yellows-resistant varieties.
Radish black root	Plant resistant varieties. Avoid planting radishes in severely infested soil.
Nematodes	Mocap (cabbage only) or Nemacur (Brussels sprout and cabbage only) may be applied at planting.
Cucurbits (cucumber, muskmelon or cantaloupe, pumpkin, squash, and watermelon)	
General	Use a crop rotation of 3 to 4 years. Grow resistant varieties whenever possible.
Seed rot, damping-off, seedborne diseases	Plant only certified, western-grown seed treated with captan or thiram. Damping-off can be treated with a captan or Ridomil 2E seed-bed drench. Plant shallow in warm soil.
Bacterial wilt	Provide season-long control of striped and spotted cucumber beetles. Start as the plants begin to emerge. Planting-time treatment with Furadan will provide moderate control for 3 to 4 weeks. Supplemental insecticide use will be necessary.
Anthracnose, scab, blossom blights, and gummy stem blight, or black rot	Grow resistant varieties when possible. Spray weekly with Bravo, Benlate, Topsin M, mancozeb, or maneb. Start when vines begin to run. Store only blemish-free fruit.
Downy mildew, Alternaria leaf blight	Practice a 2 to 3 year rotation. Grow resistant varieties when possible. Maintain ample but *not* excessive nitrogen fertility. Apply Bravo, mancozeb, or maneb on a weekly schedule. Ridomil/Bravo 81W provides excellent control of downy mildew.
Fruit spots and rots	Maintain fungicide schedule as for anthracnose throughout the season. Avoid harvest injuries.
Fusarium wilt	Grow only resistant varieties.
Angular leaf spot	Practice crop rotations of 3-4 years. Resistant cucumber varieties are available. Apply fixed copper sprays in combination with Bravo. Start applications early in the season.
Powdery mildew	Apply Bayleton at the first sign of disease and again 10-14 days later. Where Benlate or Bravo is applied to control other diseases, powdery mildew will be controlled under moderate disease pressure. Plant resistant varieties where possible.
Mosaic viruses	Control aphids and beetles in the field. Eliminate broadleaf weeds around field borders before plant establishment. Plant only mosaic-resistant cucumbers.
Root-knot nematode	Fumigate with Vapam, Telone C-17, Telone II, or Vorlex in the fall before planting or use Furadan or Vydate L at planting.

Table 3. Condensed Recommendations on Disease Management for Diseases of Commercial Vegetable Crops for 1993 (cont.)

Vegetable	Disease management practices
Eggplant	
Seed rot, damping-off, and seedborne diseases	Plant hot-water-treated seed when possible. Treat the seed with captan or thiram. Ridomil can be used for Pythium damping-off.
Phomopsis blight, Alternaria leaf spot, Cercospora leaf spot, and anthracnose	Follow good sanitary practices. Use a crop rotation of 2 to 3 years. Avoid bruising fruit; handle carefully at all times. Apply maneb on a 7- to 10-day interval beginning at first fruit cluster.
Verticillium wilt, nematodes	Fumigate the soil with Vapam, Vorlex, or methyl bromide plus chloropicrin. Planting under a black plastic mulch will help reduce disease severity. Vydate L will control nematodes.
Horseradish	
Leaf spots, white rust	Practice a 2-year field rotation with any other crop. Apply fixed-copper fungicides. Start when conditions are wet or dews are heavy. Continue until a killing frost occurs.
Brittleroot	Plant clean sets. Control leafhoppers that spread the disease agent.
Verticillium wilt, nematodes	Fumigate the soil before planting with Telone C-17.
Lettuce, Endive, Escarole	
Seed rot, damping-off, Gray mold	Treat seed with captan or thiram. In the field or seed bed, work Botran into the soil before planting and spray Botran 7 days after transplanting. Repeat when plants are 50% mature. Ridomil 5G or 2E as a soil application at seeding controls Pythium damping-off on head lettuce.
Aster yellows, mosaic viruses	Control leafhoppers and aphids throughout the season. Early season control is most important.
Rhizoctonia bottom rot, Sclerotinia drop, gray mold	Plant on raised beds and deep plow when possible. Apply Rovral or Ronalin at 3-leaf stage and again 10 and 20 days later. Botran applications as previously described may help. Use 100 gallons of water carrier per acre.
Gray mold	Apply Botran (leaf type only) at 7- to 10-day intervals.
Nematodes	Apply Telone C-17, Telone II, Vapam, or Vorlex in the field in the fall before planting. In greenhouses, steaming the soil will provide control.
Okra	
Seed rot, damping-off	Treat seed with captan or thiram plus Apron 25WP. Plant in warm, well-drained soil.
Fusarium and Verticillium wilts	Fumigate soil with Vorlex, Vapam, or methyl bromide plus chloropicrin.

Table 3. Condensed Recommendations on Disease Management for Diseases of Commercial Vegetable Crops for 1993 (cont.)

Vegetable	Disease management practices
Onions, Garlic, Leek, Chives, Shallot	
Smut, seed rot, damping-off	Treat the seed with captan or thiram. Use Methocel sticker to pellet the seed with fungicide. Use 1⅕ pounds of active ingredient to 20 pounds of seed for set onions; 6 pounds of active ingredient to 8 pounds of seed for bulb onions. Mancozeb or Ridomil can be used as an in-furrow drench at planting.
Blast, downy mildew, Alternaria purple blotch, Botrytis neck rot	Apply Rovral, Ronalin, maneb, mancozeb (dry onions only) or Bravo on a weekly schedule. Begin spraying with first ozone alert. Continue until harvest. Use Ridomil MZ58 (dry onions only) or Ridomil/Bravo 81W when downy mildew appears.
Bulb and stem nematode, root-knot nematode	Fumigate with Telone II, Telone C-15, Vapam, or Vorlex. Eradicate volunteer plants from fields with a history of bulb and stem nematode.
White rot of garlic	Apply Rovral on cloves and in furrow covering soil. Plant disease-free cloves in well-drained soil.
Fusarium basal rot	Avoid heavily infested fields. Grow resistant varieties. Cure bulbs rapidly and properly.
Storage decays	Maintain excellent control of leaf diseases in the field. Maintain dry storage conditions.
Yellow dwarf	Control aphids. Keep old and new plantings as far apart as possible. Destroy volunteer onions.
Peas	
Seed rot, seedling and seedborne diseases	Plant western-grown seed treated with captan or thiram and Apron 25WP plus an insecticide. Graphite at 1 ounce per bushel may be added to reduce friction in the drill.
Root rots	Index production fields. Avoid planting in fields with an index of 75 or higher. In fields with a lower root rot index, apply dinoseb (Premerge 3) or trifluralin preplant incorporated. Ridomil 2E in the seed furrow gives good Pythium damping-off and root rot control.
Fusarium wilt and near wilt, virus diseases	Grow resistant varieties. Viruses are spread by aphids. Plant as early as possible in well-fertilized and well-drained soil. Rotate 4 years or more.
Powdery mildew	Apply sulfur dust or spray when mildew first appears and temperatures are less than 80°F. Two applications a week apart provide good control. Plant resistant varieties.
Peppers	
Seed rot, damping-off, and seedborne diseases	Use only western-grown seed and treat with hot water or a household bleach (Clorox) soak. The bleach soak controls seedborne bacterial spot. Use 1 part bleach to 3 parts water, soak 1 minute.

Table 3. Condensed Recommendations on Disease Management for Diseases of Commercial Vegetable Crops for 1993 (cont.)

Vegetable	Disease management practices
Peppers (cont.)	Use 1 gallon of fresh bleach-water solution to 1 pound of seed. Rinse thoroughly before treating with captan or thiram seed protectant. Ridomil can be used to control Pythium damping-off.
Bacterial spot	Use crop rotations of 2 to 3 years, excluding small grains and tomatoes. Control broadleaf weeds in and around field borders. Apply fixed copper plus streptomycin (200 ppm) to seedlings. After transplanting, apply fixed copper on a 5- to 7-day interval. The addition of maneb to the copper can increase the effectiveness of the application. Purchase only certified, disease-free transplants. Planting peppers in narrow strips between early planted corn may help reduce spread during severe rain and wind storms. Maintain a high balanced level of soil fertility.
Phytophthora crown rot	Plant on raised beds in well-drained soil. Treat soil with Ridomil 2E. Rotate to nonsolanaceous crops for 3 to 4 years.
Anthracnose, Cercospora leaf spot, other fungal leaf spots, and fruit rots	Use disease-free seed. Practice 3-year crop rotation. Burn or plow down crop refuse after harvest. Apply maneb on a 7- to 10-day interval when disease first appears.
Nematodes	Add Vydate L to transplant water and supplement with foliar applications. Follow label directions.
Verticillium wilt	Fumigate soil with Vapam, Vorlex, or methyl bromide plus chloropicrin.
Virus diseases	Grow resistant varieties. Control aphids that transmit viruses. Eliminate broadleaf weeds within 150 ft of fields before crop is established. Plant only healthy transplants.
Potatoes (Irish)	
General	Purchase only certified seed. Seed-production fields should be inspected for virus, nematode, and fungal disease problems. Good sanitation and seed-handling practices will reduce losses.
Seedpiece decay, seedborne diseases, Verticillium wilt, and blackleg	Treat seed with captan, maneb, mancozeb, or TOPS 2.5D. Keep seed storage at approximately 40°F during the winter. In the spring, warm the seed to 65° to 70°F for 2 to 3 weeks before cutting. Streptomycin may be added to fungicide dusts to improve the control of bacterial diseases. Avoid bruising seed during handling.
Scab	Plant resistant varieties. Do *not* apply manure or other organic matter immediately before the potato crop. Maintain acidic soil.
Storage rots	Store healthy, sound, unbruised mature potatoes. Maintain a proper storage environment. Apply Mertect 340-F as a spray to unwashed tubers before storage. It helps control Fusarium dry rot.
Rhizoctonia	Use a Terraclor soil treatment. Practice a 3-year rotation. Avoid deep planting.
Verticillium wilt	Practice crop rotation, use only seed free of *Verticillium*. Control root-knot and root-lesion nematodes. Soil fumigation with Vapam or Vorlex may be practical.

Table 3. Condensed Recommendations on Disease Management for Diseases of Commercial Vegetable Crops for 1993 (cont.)

Vegetable	Disease management practices
Nematodes	Where soil samples indicate damaging levels of nematodes, apply Temik or Vydate L, or fumigate with Vapam, Vorlex, or Telone C-17.
Early blight and late blight, leak, pink rot	Apply maneb, mancozeb, or Bravo on 5- to 10-day schedule. Maintain an adequate supply of nitrogen throughout the season to provide good control of early blight. Use Ridomil MZ58, or Ridomil/Bravo 81W only where late blight, leak, and pink rot are a threat. Avoid bruising tubers, especially in hot weather.
Virus diseases and purple-top wilt (Aster yellows)	Plant only certified seed. Control aphids and leafhoppers with insecticides. Practice clean cultivation. Rogue first infected plants including tubers.
Rhubarb (greenhouse only)	
Botrytis leaf rot	Apply Botran (3 days to harvest) or fixed copper after budding and at weekly intervals.
Crown and root rots	Plant only in well-drained soil. Maintain optimal soil fertility. Drench the crowns with fixed copper at 3 pounds per acre in the early spring and after harvest if crown rot is a problem.
Spinach	
Seed rot and damping-off	Treat seed with captan or thiram. Apply Ridomil 2E for Pythium damping-off.
Downy mildew or blue mold and white rust	Grow downy mildew-resistant varieties. Apply Aliette as a foliar spray when conditions favor disease development and continue on a 7- to 21-day interval. A soil application of Ridomil 2E can also help control downy mildew and white rust.
Cucumber mosaic virus or blight	Grow tolerant varieties. Control aphids that spread the virus.
Sweet Potatoes	
Black rot, foot rot, Fusarium wilt, and scurf	Grow resistant varieties. Use clean soil in plant beds and maintain temperature of 80° to 85°F. Plant disease-free roots and use crop rotations of 3 to 4 years. Dip the roots or sprouts in Botran or Mertect 340-F.
Storage rots	Fumigate storage crates and houses with formaldehyde. Use Botran as a postharvest dip. Cure and store only healthy, blemish-free roots.
Nematodes	Plant resistant varieties. Practice crop rotation. Temik, Mocap, Vydate L, or Dasanit (suppression only) may be used for chemical control; or fall fumigate with Vapam or Vorlex.
Tomatoes (field)	
Seed decay, damping-off, and seedborne diseases	Plant hot-water- or household bleach-soaked seed that has been treated with captan or thiram. See treatment for pepper seed. Use Ridomil 2E drench for Pythium damping-off in the seed bed.

Table 3. Condensed Recommendations on Disease Management for Diseases of Commercial Vegetable Crops for 1993 (cont.)

Vegetable	Disease management practices
Bacterial spot, speck, and canker	Purchase only certified, disease-free plants. Use crop rotations of 3 to 4 years, excluding small grains. In the seed bed, spray with fixed copper plus streptomycin. After transplanting, spray with fixed copper plus mancozeb or Bravo C/M. Once established, bacterial spot and canker are difficult to control.
Septoria blight, early blight, anthracnose, buckeye rot, gray leaf spot, and leaf mold, gray mold, and white mold *(Sclerotinia)*	Practice 2- to 3-year crop rotation. Apply mancozeb or Bravo on a 7- to 10-day schedule after the first sign of disease or after the first fruits form. A soil surface spray of mancozeb after the last cultivation will improve anthracnose control. Benlate may be used for Botrytis, white mold, and leaf mold control. Ridomil 2E or Ridomil/Bravo 81W helps control buckeye rot, Pythium fruit rots, and late blight.
Blossom-end rot	Mulch plants or maintain uniform soil moisture. Four weekly applications of calcium nitrate starting when the fruits are grape size may reduce losses. Avoid cultivation close to plants.
Verticillium wilt and Fusarium wilt	Grow only resistant (VF) varieties. Avoid soils with a history of wilt.
Viruses	Take care to avoid infecting the seedlings. Start with virus-free seed. Control insects and broad-leaf weeds in and around fields. See greenhouse tomatoes below.
Nematodes	Plant root-knot-resistant varieties. Vydate L or Dasanit may be applied at planting. Fall fumigation with Vapam or Vorlex may also be used.
Tomatoes (greenhouse)	
Virus diseases	Start with hot-water-treated seed. Do not allow the use of tobacco on the premises. Smokers should wash their hands with soap and hot water before working with plants. If possible, plant TMV-resistant hybrids. Control insects. Remove first infected plants if possible.
Botrytis gray mold, leaf mold, gray leaf spot, and early blight	Avoid excessive humidity by heating and venting, especially at night during the fall, early winter, and early spring. Spray weekly with mancozeb or Bravo, or fumigate with Exotherm Termil. Botran as a directed spray controls stem canker; cover stems up to 18 to 24 inches from ground.
Nematodes, root rots, and soilborne TMV	Steam the plant beds. Plant resistant varieties whenever available.

Noncrop Weed Control

Noncrop Weeds

13 Brush Control in Illinois

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Brush control is used to improve and maintain pastures, recreational areas, fencerows, drainage ditch banks, rights-of-way, and other noncrop areas. Brush can be controlled by mechanical means such as cutting or digging, by herbicide treatments, or by a combination of mechanical and chemical control measures that remove the plant and prevent resprouting.

Mechanical control is costly and time-consuming. Retreatment may be required for complete control because resprouting often occurs when herbicides are not used. Herbicides are generally less time-consuming and labor-intensive than are mechanical control methods, because complete control can be achieved with one treatment if the herbicide program is carefully planned. However, chemical control alone does not remove the dead plants.

Some brush herbicides are selective; they leave grasses unharmed while controlling brush and broadleaf weeds. These herbicides can injure desirable broadleaf plants if they are allowed to drift, run off, or leach out of the treatment area. Nonselective herbicides are also potentially hazardous to desirable plants, but they can be used as spot treatments to control brush species if they are applied carefully so that they do not move from the specific treatment area.

Some herbicides used for brush control have grazing and harvest restrictions. Some cannot be applied to aquatic areas, irrigation or drainage ditches, or to areas where they could run off or leach into those water systems. Be sure to follow label restrictions and recommendations closely and to make applications carefully.

Methods of Application

Various methods can be used to get the herbicide into the target plant. Table 1 lists common brush herbicides and indicates the areas for which they are labeled, the appropriate application methods, and type of brush they control. Tables 2 through 5 describe the susceptibility of common brush species to various herbicides applied by foliar, basal-bark, cut-surface, cut-stubble, or soil application methods. The information in these tables was taken from herbicide labels and from *Response of Selected Woody Plants in the United States to Herbicides*, Agriculture Handbook No. 493, USDA.

Foliar Treatments

Foliar treatments are most effective when applied to fully developed plant foliage during late spring or early summer. Most herbicides can be applied throughout the growing season although translocation may be restricted by adverse temperature or moisture stress. Good foliar coverage is necessary for control, and some products should be applied so that they also drench the stem.

The effectiveness of some foliar herbicides can be reduced if rainfall occurs on the day of treatment. Foliar treatments should usually be applied only to shrubs or small trees. Large trees should be treated by another method to improve control and reduce drift potential.

When making foliar applications, take precautions against particle drift from the spray to nearby susceptible plants. Do not spray when the wind velocity is greater than 5 miles per hour or when the wind is blowing toward sensitive crops or ornamentals. Reduce the spray pressure and use nozzles with large orifices to apply herbicides that do not require coverage with fine spray droplets to achieve good control. Drift-reducing spray additives and equipment are available, but to achieve good control and to ensure minimum drift, you must adhere closely to all label precautions and directions. Certain formulations volatilize and should not be used when drift prevention is crucial. Some herbicide labels list sensitive species and areas that must be protected from drift and direct application.

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

Basal-Bark Treatments

Basal-bark herbicides are oil-soluble herbicides applied as purchased or in a carrier of diesel oil, fuel oil, kerosene, or other recommended oil. There are four types of basal-bark applications: thinline, low-volume banding, low-volume basal, and conventional basal. Any of these techniques can be used during the dormant or growing season to control woody plants with stems less than 6 inches in diameter.

Thinline application is an application of herbicide in an even, pencil-thin stream to all sides of the stems about 6 inches above groundline. The treated area will expand to about a 2-inch width, and except for smooth-barked species, little rundown will occur.

Low-volume banding is an application of 35 to 50 percent herbicide in an oil diluent to all sides of the woody stem in a 3- to 4-inch-wide band at any height up to 3 feet above the groundline. The treated area will expand to about a 6-inch width, and except for smooth-barked plants, little rundown will occur.

Low-volume basal is an application of 20 to 30 percent herbicide in an oil diluent to all sides of the lower 12 to 15 inches of stems, including the root collar. The herbicide must be applied in a manner which adequately wets the stem, but not to the point of runoff.

Conventional basal is an application of 1 to 3 percent herbicide in oil to all sides of the lower 12 to 15 inches of stems, including the root collar. Thorough wetting of the indicated area and spraying to the point of runoff is necessary.

The herbicides commonly used for basal-bark treatments can cause injury if the vapors or particles drift to desirable crops or ornamentals. Although basal-bark treatments can be made throughout the year, applications made during the dormant season are less likely to result in injury from any drift that may occur. Do not apply when snow prevents treating the bark to the groundline. Some species, such as maples, should not be treated during heavy sapflow. Basal-bark treatments are more labor-intensive than foliar treatments, but they are useful as a technique to selectively remove undesirable species from stands of desirable trees. They are also useful where brush density is low to moderate. In addition, they are less prone to drift injury.

Cut-Surface Treatments

Cut-surface treatments are more effective than basal-bark treatments on thick-barked species and on plants that are greater than 5 inches in diameter. The herbicide is applied to the stump of a cut plant or to frills or notches (girdles) cut around the plant to a depth of at least 1/2 inch into the sapwood. Continuous cuts rather than spaced notches or frills may be more effective for difficult-to-control species. Special injection equipment can be used to cut into the plant and apply the herbicide in one operation. The herbicide should be applied to the cut surface before the exposed plant tissue dries, which is usually within two or three hours after cutting. When treating cut stumps, thoroughly drench the cambium area next to the bark but not to the point of runoff. Cut-surface applications can be made during any season of the year, but application during the dormant season minimizes the potential for drift injury.

Cut-Stubble Treatments

Cut-stubble treatments are broadcast applications of herbicide in a water carrier to cut stumps and exposed ground following a mowing operation. Any ground-spray method that will evenly distribute the herbicide over the treated area can be utilized. This application technique can be used throughout the year except when the ground is frozen or completely saturated with water. Apply when any runoff will be minimal.

Soil Treatments

Soil treatments can be made with certain herbicides that move through the soil to the root zone and then translocate upward to kill the plant. Soil treatments are applied within the dripline of the target species either as sprays, or in dry form as granules, beads, or pellets. Apply these herbicides carefully to minimize injury to nearby desirable species. Nontarget injury can result if the herbicide moves laterally in the soil or in treated areas where the root zones of desirable and target species overlap.

Most soil treatments should be made between the last hard frost in spring and the first hard frost in autumn. Soil treatments should not be applied to frozen ground. Many soil-applied herbicides remain active in the soil for several months; for this reason, do not use soil-applied herbicides where they might run off into water sources or leach into groundwater.

Brush Herbicides

Phenoxy

Phenoxy herbicides used for brush control are 2,4-D and dichlorprop (2,4-DP). These herbicides are sold under several different trade names. The 2,4-D label indicates usage for brush control in pastures, drainage ditch banks, rights-of-way, and noncrop areas. Dichlorprop is labeled for use on rights-of-way and noncrop areas. Other herbicides are sometimes combined with 2,4-D or dichlorprop to broaden the spectrum of susceptible plants. Dichlorprop plus 2,4-D is available commercially as **Weedone 170** or **Weedone CB**.

The phenoxy herbicides are readily absorbed by plant foliage. Oil-soluble formulations (esters or oil-soluble amines) applied in kerosene or diesel oil carriers will penetrate the bark of most woody plants. The esters are usually more effective than the amines for treating brush and trees with foliar or basal-bark sprays. Amines are preferable for injection and cut-surface treatments.

A minute amount of phenoxy herbicide may cause injury to highly susceptible nontarget plants such as tomatoes, grapes, cucumbers, and ornamentals—whether the method of application is foliar, basal-bark, or cut-surface. Generally a foliar treatment is potentially more hazardous than the other methods because it requires a greater volume of herbicide spray solution. The vapors from a phenoxy herbicide may travel up to one-half mile. To reduce vapor drift, use an amine rather than an ester formulation when possible. Do not use an ester when the temperature on the day of treatment might exceed 85°F. Do not treat in the vicinity of sensitive nontarget plants. Do not apply phenoxy herbicides to water intended for domestic use or irrigation.

If possible, do not use phenoxy spray equipment to apply other pesticides to phenoxy-susceptible plants. Some residue may remain even after thorough cleaning. Follow all use restrictions listed on the herbicide label.

Banvel

Banvel (dicamba) is a selective, translocated herbicide that can be absorbed through roots or aboveground portions of plants. Banvel is used for foliar, cut-surface, or basal-bark treatments. For multiflora rose control, a spot concentrate application of Banvel to the soil can be made. Spray the soil as closely as possible to the crown root (within 6 to 8 inches of the crown). Foliar sprays can be applied with ground or aerial equipment, but aerial application should not be made in the vicinity of sensitive plants. The spectrum of species controlled with Banvel can be broadened by the addition of 2,4-D as recommended on the label. Premixed products include **Weedmaster,** which is 2,4-D plus dicamba at 2.87 pounds plus 1-pound-per-gallon.

Like the phenoxys, Banvel volatilizes readily and is effective in small amounts. Prevent drift to sensitive feed and food crops, ornamentals, and conifers. Do not apply Banvel when the temperature is expected to exceed 85°F within several days of the application. Because Banvel is root absorbed, do not treat areas where the herbicide may leach or run off and contact the roots of desirable plants.

The label restricts the use of Banvel near soybeans in certain stages of growth. Grazing and harvest intervals are stated on the label. Study the label carefully before applying Banvel. If possible, do not use equipment used to spray Banvel to apply other pesticides to Banvel-susceptible plants because some residue may remain even after thorough cleaning.

Tordon

Tordon (picloram) is a selective, translocated herbicide that is absorbed by plant roots and foliage. Formulations are available for foliar, basal-bark, soil, or cut-surface applications. Mixtures with phenoxy herbicides (**Tordon 101 Mixture, Tordon RTU,** and **Pathway**) or with triclopyr (**Access**) are available to give broader-spectrum weed control.

Applications can be made to either foliage or soil. With soil treatments, control is enhanced as rainfall moves the herbicide into the root zone. Broadcast foliar or soil treatments are recommended for dense brush. Spot treatments can be made to individual plants or scattered stands of brush. Tordon products can be mixed with other herbicides to provide a broader spectrum of broadleaf weed and woody plant control.

A low concentration can cause extensive damage to susceptible species. Do not apply where runoff or leaching could move the herbicide into the root zone of susceptible nontarget plants, such as conifers or broadleaf ornamentals and crops. Prevent picloram from drifting into water containments and areas where desirable plants are growing. Drift injury to nontarget species is much less likely to result in injury if treatment is made during the dormant season.

Tordon K, Tordon 101, and Access are restricted-use herbicides (RUP) that can be applied only by certified private or commercial applicators. Tordon RTU and Pathway, which are premixed and labeled for cut-surface application only, are general-use herbicides.

Garlon

Garlon (triclopyr) is a selective, translocated herbicide that can be applied as a foliar, basal-bark, or cut-surface treatment. Basal-bark treatments can be applied throughout the year. Compared to many brush herbicides, Garlon gives superior control of ash, oak, and certain rootsprouting species, such as sassafras and black locust. Commercial mixes of triclopyr plus 2,4-D (1:2) **(Crossbow)** or triclopyr plus picloram **(Access)** are available to control a broader spectrum of brush species. Take measures to prevent drift of Garlon formulations to susceptible ornamentals, crops, and conifers. The ester formulation is toxic to fish.

2,4-D + dicamba + MCPP

Trimec 352, Brush Killer 875, Acme Super Brush Killer, and other commercial mixtures of 2,4-D, mecoprop (MCPP), and dicamba are designed for foliar applications to give broad-spectrum brush control. Acme Super Brush Killer is also labeled for cut-surface and dormant season basal-bark applications. A low concentration can damage susceptible species. Prevent drift injury.

Escort

Escort (metsulfuron) is labeled for the control of herbaceous and woody broadleaf plants. It is available as a 60 percent, dry flowable formulation labeled for foliar application at rates of 1/3 to 2 ounces per acre. For greatest effectiveness, the herbicide should be applied to completely cover the foliage and stems. The application can be made any time between one-half leaf stage in the spring until just before autumn leaf coloration. Plants are most susceptible when the application is made during warm, moist conditions and less susceptible when the weather is cool or dry. Woody species listed on the label include ash, cherry, elm, oak, red maple, and multiflora rose. Escort is most effective against broadleaf species. However, at medium to high label rates it can suppress or severely injure certain grasses. Read the label before making applications, especially near desirable grasses.

Escort is labeled for use in noncrop areas, such as airports, roadsides, and utility, pipeline, and railroad rights-of-way. It should not be used on lawns, walks, driveways, tennis courts, or similar areas.

Escort injury symptoms (leaf discoloration) can take several weeks to appear, depending on environmental conditions. However, treated plants stop growth very soon after the application.

Do not apply the herbicide or drain or rinse application equipment near desirable plants, or on soil where roots of desirable plants may extend, or in locations where the herbicide may be moved into contact with the roots. Do not use spray equipment to apply products to desirable plants after it has been used to apply Escort because low rates of Escort can kill or severely injure desirable plants.

Krenite

Krenite (fosamine) is a contact herbicide that is applied to the foliage of brush during the two-month period before autumn leaf coloration. No effects are seen until the following spring, when treated plants fail to refoliate and subsequently die. Pine species may respond during the season of treatment. Thorough coverage is required for complete control. By carefully directing the application, you can use Krenite to trim woody species without killing the entire plant. A surfactant can be used to improve control.

Krenite should not be applied to desirable plants, brush standing in water, or food crops. Krenite can be slightly corrosive to brass or copper spray equipment. Clean thoroughly after use to protect spray equipment.

Roundup

Roundup (glyphosate) is a nonselective, translocated herbicide, which can be used for spot treatments in areas where loss of ground cover is detrimental. Because plants absorb the herbicide through their foliage, glyphosate must be applied during the season of active growth. Flowering species should be treated when the plants are at or beyond the full-bloom stage of growth. Roundup has no soil activity. Prevent drift to foliage of nontarget species. Roundup can be tank-mixed with certain other herbicides indicated on the label to broaden the spectrum of control.

Arsenal, Chopper

Arsenal (imazapyr) is a 2-pound-per-gallon formulation that is taken up by both foliage and roots and translocated to the meristems. Arsenal A.C. is a 4-pound-per-'gallon aqueous solution formulation for forestry use. Imazapyr controls annual and perennial grasses and broadleaves and a broad spectrum of woody species. Arsenal can be applied preemergence or postemergence, but postemergence is the method of choice, especially to control perennials. Arsenal usually provides residual soil activity after a postemergent application. Prevent drift to desirable plants. Do not apply to irrigation ditches, and prevent runoff to crop land. Arsenal is corrosive to mild steel, brass, and copper. **Chopper** is a 2-pound-per-gallon imazapyr formulation for basal or cut-surface application; this product requires the addition of an appropriate carrier. **Chopper RTU** is a 0.255-pound-per-gallon (3.6 percent), ready-to-use basal or cut-surface formulation.

Hyvar

Hyvar (bromacil) is a nonselective herbicide that is labeled for use on a wide spectrum of woody species. Two formulations are available: **Hyvar X**, which is an 80 percent wettable powder, and **Hyvar X-L**, which is a 2-pound-per-gallon water-soluble liquid formulation that stays in solution without continuous agitation. Both formulations are labeled for broadcast soil application on noncrop areas and rights-of-way. The recommended application time is just before emergence or during the period of active growth of the plants to be controlled. Hyvar X-L can be applied as a basal-bark or soil application in noncrop areas and rights-of-way as well as in drainage ditches.

In addition to controlling brush species, Hyvar also controls herbaceous broadleaf and grass plants. Grass species are especially susceptible to injury. Spot treatments around the base of woody plants may be appropriate in areas where bare ground is undesirable.

Injury symptoms are generally slow to appear. Treated plants may not respond until the herbicide has been carried into the root zone by rainfall. In areas of dense growth, results will be improved if vegetation is removed before Hyvar is applied.

Do not apply to frozen soil or to brush standing in water. Do not use water from treated ditches for irrigation, and do not treat ditches that are adjacent to desirable plants.

Hyvar X is noncorrosive, nonflammable, and nonvolatile. Hyvar X-L is corrosive to aluminum and should not be applied with aluminum spray nozzles. Undiluted Hyvar X-L is combustible, so it must be kept away from heat and open flame. Do not smoke when handling this product.

Velpar

Velpar (hexazinone) is a nonselective herbicide that is taken up by the roots and foliage of plants. Velpar is most effective when applied to the soil just before or soon after weed emergence. Velpar also has some contact activity if an appropriate surfactant is added to the spray mix. The recommended rate varies with soil type. Higher rates are recommended when treating hard-to-control species. Avoid application of Velpar to the root zone or foliage of desirable plants. Spot treatment is necessary when bare soil is undesirable. Exceeding the concentration recommended on the label might clog nozzles and result in uneven distribution. Agitate the herbicide mixture for at least ten minutes until Velpar is thoroughly dissolved.

Spike

Spike (tebuthiuron) is a soil-applied nonselective herbicide that is absorbed by the roots of plants. It is available as an 80 percent wettable powder, in 1-pound water-soluble packets, or as pellets. Spike can be applied any time, except when the ground is frozen or the soil is saturated with moisture. To achieve the best results, apply the herbicide before or during active growth of target plants. Spike can be applied to the soil dry or with a water carrier. The dry application requires rainfall to wash the herbicide into the root zone.

Because of differences in susceptibility, different species require different rates of Spike. Consult the label for the correct rate of use for the plant species to be controlled. Spike can be broadcast or applied as an individual plant treatment, depending on the size, density, and location of the brush to be controlled.

The wettable powder formulation requires continuous agitation. Avoid application where runoff can move the herbicide into nontarget areas. Prevent drift or direct application of Spike to the root zones of desirable plants.

Table 1. Label Clearances: Common Brush Herbicides

	Area					Application					Type of brush	
Brush herbicide	Pasture	Forest	Ditch bank	Right-of-way	Non-crop	Foliar-stem spray	Cut surface; injection	Conventional basal[a]	Low volume basal	Soil	Deciduous	Conifer
2,4-D amine	x	x	x	x	x	x	x	..	..	..	x	..
2,4-D ester	x	x	x	x	x	x	x	x	x	..	x	..
2,4-DP (dichlorprop)	..	..	..	x	x	x	x	x	..	..	x	..
Weedone 170 or Weedone CB (2,4-D + dichlorprop)	..	x	x	x	x	x	x	x	x	..	x	x
Acme Super Brush Killer (2,4-D + dichlorprop + dicamba)	..	x	x	x	x	x	x	x	..	..	x	x
Banvel	x	x	x	x	x	x	x	x[b]	..	x[g]	x	..
Weedmaster (dicamba + 2,4-D)	x	..	x	x	x	x	x	..	..	..	x	x
Garlon 3A (triclopyr amine)	..	x	x	x	x	x	x	..	..	..	x	x
Garlon 4 (triclopyr ester)	..	x	x	x	x	x	..	x	x	..	x	x
Tordon K (picloram)	..	x	..	x	x	x	..	..	..	x	x	x
Tordon RTU or Pathway (picloram + 2,4-D)	..	x	x	x	x	..	x	..	..	..	x	x
Tordon 101 Mixture (picloram + 2,4-D)	..	x	..	x	x	x	x	..	..	x	x	x
Access (esters of picloram + triclopyr)	..	..	..	x	x	..	..	x	x	..	x	x
Crossbow (triclopyr + 2,4-D)	x	..	x[c]	..	x	x	..	x	x	..	x	x
Trimec 352 (2,4-D + mecoprop + dicamba)	..	x	x	x	x	x	x	..	..	..	x	x
Escort (metsulfuron)	..	..	..	x	x	x	..	..	..	..	x	..
Krenite	..	x	x	x	x	x	..	..	..	..	x	..
Arsenal	..	..	x	x	x	x	x	..	..	..	x	..
Arsenal A.C.	..	x	..	..	..	x	x	..	..	..	x	..
Chopper (imazapyr)	..	x	x	x	x	..	x	x	x	..	x	..
Chopper RTU (imazapyr)	..	..	..	x	x	..	x	x	x	..	x	..
Roundup	x[d]	x	x	x	x	x	..	..	..	..	x	..
Hyvar-X	..	..	x[e]	x	x	x	..	..	..	x	x	x
Velpar	..	x	..	x	x	x	..	..	..	x	x	..
Spike	x[f]	..	x[f]	x	x	..	..	..	..	x	x	x

x = labeled for use; .. = not labeled for use.
[a]Oil-soluble forms only.
[b]Not for pasture use.
[c]Nonirrigation ditch banks only.
[d]Spot treatment only (10 percent of each acre).
[e]Soil application only.
[f]See specific formulation label.
[g]Granular formulation.

Table 2. Foliar Herbicide Treatment: Susceptibility of Common Brush Species

	2,4-D	Weedone 170[a]	Acme SBK	Banvel	Weed-master[b]	Tordon101[c]	Hyvar	Garlon	Crossbow[d]	Escort	Roundup	Krenite	Arsenal
Ash, white (*Fraxinus americana*)	R	R	S	S-R	R	I	S-R	S	S	S	I	I	S
Birch (*Betula* spp.)	I	S	S	S	S-I	S	S	S	S-I	R	I	S-I	R
Boxelder (*Acer negundo*)	I	I	...	...	I	S	S	S	S-I	R	I	I	R
Brambles—blackberry, raspberry, etc. (*Rubus* spp.)	I-R	I-R	S	S-I	I	S	S-I	S	S	R	R	S-I	R
Cherry, black and choke (*Prunus serotina* and *P. virginiana*)	I-R	I-R	S	S	R	S	S-I	S-I	S-I	S	S-I	I	S
Cottonwood, eastern (*Populus deltoides*)	S-R	R	S	R	R	S	S-I	S	S-I	R	R	S-I	R
Crabapple (*Pyrus ioensis*)	I-R	S	...	S	S	S	S	S-I	S	...	S	...	...
Elderberry (*Sambucus canadensis*)	I	I	...	S	S	S	S	S	S-I	R	S-I	I	R
Elms, American and slippery (*Ulmus* spp.)	I	S-I	S	I	R	S	S-I	S-I	S-I	S	I	S-I	I-R
Grapes, wild (*Vitis* spp.)	S-I	S-I	...	I-R	I	S	...	S	S-I	I	I	S-I	S
Greenbrier or catsbriar (*Smilax* spp.)	R	R	...	R	R	R	R	S-I	R	R	R	R	S
Hackberry (*Celtis* spp.)	I-R	I-R	...	I	I	S	S-I	S	S	R	I	R	R
Hawthorn (*Crataegus* spp.)	I-R	R	...	R	R	S	...	S	I	R	I	I	S
Hedge-apple or osage orange (*Maclura pomifera*)	R	R	...	I-R	R	S-I	...	S-I	I	R	R	R	R
Honeylocust (*Gleditsia triacanthos*)	I-R	I	S	S-I	I	S	S	S-I	S-I	R	I	R	S
Honeysuckle (*Lonicera* spp.)	I	I	S	I	I	S	S	S-I	S-I	R	S-I	R	S
Locust, black (*Robinia pseudoacacia*)	I	S-I	S	S	S	S	S	S	S	R	S	S	S-I
Maple (*Acer* spp.)	I-R	R	S	I-R	R	S	S	S	S	I	S-I	S-I	S
Mulberry, red (*Morus rubra*)	I-R	R	...	S-I	I	S	...	S	S	R	...	R	S
Oak (*Quercus* spp.)	...	...	S	...	...	S-I	...	S-I	S-I	...	...	...	S
Persimmon, eastern (*Diospyros virginiana*)	I	I-R	...	S-I	I	S-I	...	S-I	I	R	R	R	R
Plum, wild (*Prunus* spp.)	S-I	I	S	S-I	I	S-I	...	S-I	S-I	R	I	I	S
Poison ivy (*Rhus radicans*)	I	I	S	S	S	S	S	S	S	R	R	R	S
Redcedar, eastern (*Juniperus virginiana*)	R	I-R	S	I-R	R	S-I	S	R	R	I	S-I	I	R
Rose, multiflora (*Rosa multiflora*)	R	S	S	...	...	S	...	S	S	S	R	S-I	S
Sassafras (*Sassafras albidum*)	I	I	...	I	I	S	S	S-I	I	R	I	R	S
Sumac (*Rhus* spp.)	S-I	S	S	S	S	S	S-I	S	S	R	I	I	S
Tree-of-heaven (*Ailanthus altissima*)	I	I	...	S-I	S-I	S-I	S	S	S-I	R	I	S-I	I-R
Trumpetcreeper (*Campsis radicans*)	R	R	S	S-I	I	S-I	...	S-I	S-I	R	R	I	S
Virginia creeper (*Parthenocissus quinquefolia*)	S-I	I	...	...	I	I	...	S	S	R	I	R	S
Willow (*Salix* spp.)	S	S	S	S-I	S	S	S	S	S	R	I	I	S

S = Susceptible; I = Intermediate; R = Resistant; S-I = Susceptible to Intermediate, S-R = Susceptible to Resistant, I-R = Intermediate to Resistant; ... = no information available. Data are adapted from *Response of Selected Woody Plants in the United States to Herbicides*, Agricultural Handbook No. 493, U.S. Department of Agriculture, and from herbicide companies.

[a]Weedone 170 = dichlorprop + 2,4-D
[b]Weedmaster = dicamba + 2,4-D
[c]Tordon 101 = picloram + 2,4-D
[d]Crossbow = triclopyr + 2,4-D

Table 3. Conventional Basal-Bark Herbicide Treatment: Susceptibility of Common Brush Species

	2,4-D ester	dichlor-prop	Weedone CB[a]/ Weedone 170[a]	Banvel	Access[b]	Acme Super Brush[c]	Garlon 4[d]	Chopper/ Chopper RTU
Ash, white (*Fraxinus americana*)	R	I	R	S-I	S	R	S	S
Birch (*Betula* spp.)	S	I	I	...	S	I	S	S
Boxelder (*Acer negundo*)	S	S	...	S	S	R	S	S
Brambles—blackberry, raspberry, etc. (*Rubus* spp.)	I-R	I-R	I	S	S	I	S	I
Cherry, black and choke (*Prunus serotina* and *P. virginiana*)	S-R	I-R	I	S	S	I	S	S
Cottonwood, eastern (*Populus deltoides*)	...	R	R	...	S	R	S	S
Crabapple (*Pyrus ioensis*)	S-I	S-I	S-I	S	S	...	...	...
Elderberry (*Sambucus canadensis*)	S-I	S	S-I	S	S	R	S	S
Elms, American and slippery (*Ulmus* spp.)	S-I	S-I	S-I	S	S	I	S-I	I-R
Grapes, wild (*Vitis* spp.)	...	R	R	...	S	I	S-I	S
Greenbrier or catsbriar (*Smilax* spp.)	I	R	R	R	I-R	R	R	S
Hackberry (*Celtis* spp.)	S	S	S	...	S	R	S	R
Hawthorn (*Crataegus* spp.)	I	S-I	I	S-R	S	R	S-I	...
Hedge-apple or osage orange (*Maclura pomifera*)	I	R	R	...	S	R	S-I	R
Honeylocust (*Gleditsia triacanthos*)	I	I	I	...	S	I	S	I-S
Honeysuckle (*Lonicera* spp.)	S	S-I	S	S	S	R	R	S
Locust, black (*Robinia pseudoacacia*)	I	I-R	I	S-I	S	I	S	S-I
Maple (*Acer* spp.)	I-R	R	I	S-I	S	R	S	S
Mulberry, red (*Morus rubra*)	I-R	I-R	I-R	S	S	R	S	S
Oak	R	S	S	S	S	...	S	S
Persimmon, eastern (*Diospyros virginiana*)	I-R	R	R	S	S	R	S	S
Plum, wild (*Prunus* spp.)	S-I	S-I	S-I	S	S	I	R	S
Poison ivy (*Rhus radicans*)	I	I	I	...	S	I	S	S
Redcedar, eastern (*Juniperus virginiana*)	R	R	...	S-I	S	I	R	R
Rose, multiflora (*Rosa multiflora*)	I	I	I	...	S	S	S	S
Sassafras (*Sassafras albidum*)	S-I	S-R	R	S	S	R	S-I	S
Sumac (*Rhus* spp.)	I	R	I	S	S	S	S	S
Tree-of-heaven (*Ailanthus altissima*)	S-R	I	I	S	S	R	S	I
Trumpetcreeper (*Campsis radicans*)	R	R	R	...	I	I	I	S
Virginia creeper (*Parthenocissus quinquefolia*)	...	R	R	...	...	R	R	S
Willow (*Salix* spp.)	S	S	S	...	S	S	S	S

S = Susceptible, I = Intermediate, R = Resistant, S-I = Susceptible to Intermediate, S-R = Susceptible to Resistant, I-R = Intermediate to Resistant; ... = No information available. Data are adapted from *Response of Selected Woody Plants in the United States to Herbicides*, Agriculture Handbook No. 493; U.S. Department of Agriculture, and from herbicide companies.

[a]Weedone CB or Weedone 170 = dichlorprop + 2,4-D
[b]Access = triclopyr + picloram
[c]Acme Super Brush = 2,4-D + mecoprop (MCPP) + dicamba
[d]Garlon 4 = triclopyr ester

Table 4. Injection and Cut-Surface Treatment: Susceptibility of Common Brush Species

	2,4-D amine	Weedone 170[a]	Garlon 3A[b]	Banvel	Tordon RTU[c]	Acme Super Brush[d]	Round-up	Arsenal/ Chopper
Ash, white (*Fraxinus americana*)	R	I	S	S	S	I	I	S
Birch (*Betula* spp.)	I	S-I	S	S	S	I	I	S
Boxelder (*Acer negundo*)	I	I	S	...	S	I	I	S
Cherry, black and choke (*Prunus serotina* and *P. virginiana*)	S	S-I	S-I	...	S	I	I	S
Cottonwood, eastern (*Populus deltoides*)	S	I	S	...	S	S	I	S
Crabapple (*Pyrus ioensis*)	...	...	S	...	...	...	...	...
Elderberry (*Sambucus canadensis*)	I	R	S-I	...	S	R	I	S
Elms, American and slippery (*Ulmus* spp.)	S	I	S-I	...	S-I	I	I	I
Grapes, wild (*Vitis* spp.)	S-I	R	S-I	...	S-I	I	I	I
Greenbrier or catsbriar (*Smilax* spp.)	R	S	R	...	R	R	R	S
Hackberry (*Celtis* spp.)	I	I	S	...	S	I	I	R
Hawthorn (*Crataegus* spp.)	I	I	S	...	S-I	I	I	...
Hedge-apple or osage orange (*Maclura pomifera*)	I	I	I	...	I	I	R	R
Honeylocust (*Gleditsia triacanthos*)	I	S	S-I	...	S	I	I	I
Honeysuckle (*Lonicera* spp.)	R	I	R	...	S	R	I	S
Locust, black (*Robinia pseudoacacia*)	S	S-I	S	...	S	S	I	I
Maple (*Acer* spp.)	R	I	S	S-I	S	R	R	S
Mulberry, red (*Morus rubra*)	...	I	S-I	...	S	I	R	S
Oak	R	S	S	R	S	S	S	S
Persimmon, eastern (*Diospyros virginiana*)	I	I	S	S	S-I	I	I	S
Plum, wild (*Prunus* spp.)	I	I	S-I	...	I	I	I	S
Poison ivy (*Rhus radicans*)	I	S-I	S	...	S	I	S	S
Redcedar, eastern (*Juniperus virginiana*)	R	I	R	S-I	S	I	I	R
Rose, multiflora (*Rosa multiflora*)	R	S	S	...	S	I	R	S
Sassafras (*Sassafras albidum*)	I	I	S	...	S	R	I	S
Sumac (*Rhus* spp.)	S	S	S	...	S	S	I	S
Tree-of-heaven (*Ailanthus altissima*)	I	R	S	...	S	I	I	I
Trumpetcreeper (*Campsis radicans*)	I	R	I	...	I	I	I	S
Virginia creeper (*Parthenocissus quinquefolia*)	R	R	I	...	I	R	R	S
Willow (*Salix* spp.)	S	S-I	S	...	S	I	I	S

S = Susceptible, I = Intermediate, R = Resistant, S-I = Susceptible to Intermediate, S-R = Susceptible to Resistant, I-R = Intermediate to Resistant; ... = No information available. Data are adapted from *Response of Selected Woody Plants in the United States to Herbicides*, Agriculture Handbook No. 493, U.S. Department of Agriculture, and from herbicide companies.

[a]Weedone 170 = 2,4-D + dichlorprop
[b]Garlon 3A = triclopyr amine
[c]Tordon RTU = picloram + 2,4-D
[d]Acme Super Brush = 2,4-D + mecoprop (MCPP) + dicamba

Table 5. Soil Herbicide Treatment: Susceptibility of Common Brush Species

	Hyvar	Velpar	Spike
Ash, white (*Fraxinus americana*)	S	I	I
Birch (*Betula* spp.)	S	I	I
Boxelder (*Acer negundo*)	S	I	S
Brambles—blackberry, raspberry, etc. (*Rubus* spp.)	S	I	I
Cherry, black and choke (*Prunus serotina* and *P. virginiana*)	S-I	I	S
Cottonwood, eastern (*Populus deltoides*)	...	I	S
Crabapple (*Pyrus ioensis*)	I	I	...
Elderberry (*Sambucus canadensis*)	S	S	I
Elms, American and slippery (*Ulmus* spp.)	S	I	S
Grapes, wild (*Vitis* spp.)	R	I	R
Greenbrier or catsbriar (*Smilax* spp.)	R	R	I
Hackberry (*Celtis* spp.)	S-I	I	S
Hawthorn (*Crataegus* spp.)	S-R	I	S
Hedge-apple or osage orange (*Maclura pomifera*)	R	I	...
Honeylocust (*Gleditsia triacanthos*)	S	S	I
Honeysuckle (*Lonicera* spp.)	I-R	R	R
Locust, black (*Robinia pseudoacacia*)	S	I	S
Maple (*Acer* spp.)	S-I	I	S-I
Mulberry, red (*Morus rubra*)	I	I	I
Oak	...	...	...
Persimmon, eastern (*Diospyros virginiana*)	R	I	I-R
Plum, wild (*Prunus* spp.)	S	I	S
Poison ivy (*Rhus radicans*)	S	I	I-R
Redcedar, eastern (*Juniperus virginiana*)	S	I	S
Rose, multiflora (*Rosa multiflora*)	I	S	S
Sassafras (*Sassafras albidum*)	R	R	R
Sumac (*Rhus* spp.)	S-I	I	S
Tree-of-heaven (*Ailanthus altissima*)	S-I	I	S
Trumpetcreeper (*Campsis radicans*)	R	R	S-I
Virginia creeper (*Parthenocissus quinquefolia*)	R	R	S-I
Willow (*Salix* spp.)	S	I	S

S = Susceptible, I = Intermediate, R = Resistant, S-I = Susceptible to Intermediate, S-R = Susceptible to Resistant, I-R = Intermediate to Resistant, ... = No information available. Data are adapted from *Response of Selected Woody Plants in the United States to Herbicides*, Agriculture Handbook No. 493, U.S. Department of Agriculture, and from herbicide companies.

14 Weed Control for Noncrop Areas

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Total vegetation management is the application of nonselective chemicals or nonselective rates of selective chemicals as a means of controlling all vegetation in such noncrop areas as parking lots, drive-in theater lots, driveways, and certain industrial sites.

Herbicides can be classified by their length of control. Those with little or no residual activity are the contact herbicides. Contact herbicides, such as paraquat, control only the existing vegetation that the spray contacts.

Amitrole, 2,4-D, and DSMA give residual control for four months or less. Products that provide longer control include bromacil, diuron, tebuthiuron, Oust, and prometon.

Total vegetation management is desirable along fences, beneath asphalt pavement, along railroads, and around buildings as a means of preventing the growth of weeds that are unsightly or weeds that present a fire hazard. As an alternative to chemical control in some noncrop areas, it may be preferable to establish desirable, competitive vegetation to discourage weed growth and to provide protective soil and wildlife cover. Herbicides with little or no residual activity can be used for temporary control until desirable vegetation is established.

Precautions and General Procedures

Several precautions must be observed when nonselective chemicals are used. Know what weeds are to be controlled and select the correct chemical for those particular problems. Survey the area, noting any desirable vegetation in the immediate or adjacent areas that could be affected by spray drift, chemical runoff, or herbicide leaching into the root zone.

Appropriate precautions should be taken to prevent damage to desirable plants. The risk of injury with some of these materials may be too great to allow their use in some areas. Be certain that you are familiar with the product and be aware of the risks before using any of these herbicides. Some treatments should be made only by professional applicators.

The type of vegetation to be controlled will affect your choice of a chemical. For example, perennial grasses can be controlled with Horizon, Horizon 2000, Touchdown, amitrole, asulam, or DSMA; woody perennials can be controlled with Krenite, picloram, triclopyr, 2,4-D, or mixtures of some of these products. Deep-rooted vines, such as bindweed, can be controlled with dicamba, triclopyr, picloram, or premixes of these herbicides.

Application timing is very important. The best time to apply nonselective, soil-residual herbicides is early in the spring before herbaceous weeds have emerged. If vegetation is dense, it may be necessary to mow or cut existing vegetation. For a later application, add a contact or translocated foliar herbicide, or mix the herbicides with diesel fuel to speed topkill. Follow label recommendations. After existing vegetation is under control, the rate of the soil herbicides can be reduced for maintenance applications.

Adjust application rates according to the soil type or the desired length of control. When you want to control growth for two or three years, several maintenance applications are better than one initial treatment at a high application rate.

Herbicides for Noncropland

Herbicides for Long-Term Control

Granular or pelleted materials are applied dry, which makes them convenient for spot treatment or application on small areas. Care should be taken not to apply bromacil, hexazinone, and tebuthiuron too close to trees and shrubs. Because of root uptake, these herbicides can be lethal to desirable species. Oaks are especially sensitive.

Asulam (Asulox) is a 3.34-pound-per-gallon formulation that is used at the rate of 1 to 2 gallons per acre. Asulam controls grasses more effectively than it con-

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The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

trols broadleaf weeds.

Bromacil (Hyvar-X) has both foliar and soil activity. It is formulated as an 80 percent wettable powder (WP) and a 2-pound-per-gallon liquid (X-L). The rate of active ingredient is 5 to 15 pounds per acre.

Bromacil + diuron (Krovar I) is formulated as an 80 percent dry flowable, 1:1 combination of bromacil to diuron. It is used to control shallow germinating weeds and deep-rooted perennials. The rate is 6 to 30 pounds per acre. Krovar II is a 2:1 bromacil:diuron 80 percent dry flowable formulation.

Prometon (Pramitol) is available as a 2-pound-per-gallon liquid (Pramitol 25E) and a 5 percent pellet (Pramitol 5PS). Prometon has more foliar activity than atrazine. The rate for the liquid is 5 to 10 gallons per acre.

Hexazinone (Velpar) is available as a 90 percent water-soluble powder (WSP), a 2-pound-per-gallon liquid (L), and a 75 percent granular formulation (G). Apply 2 to 5 pounds WSP or 1 to 2-1/2 gallons L per acre for contact kill and short-term control. Hexazinone is highly water soluble and may run off to damage vegetation in adjacent areas.

Tebuthiuron (Spike) is available as an 80W in water-soluble packets and as 20 and 40 percent granules (20P and 40P, respectively). Activity becomes apparent during the growing season within a few days after sufficient rainfall has moved Spike's active ingredient into the root zone. Use rates are 1.25 to 7.5 pounds per acre of 80W, 3.75 to 30 pounds per acre of 20P, and 2.5 to 15 pounds per acre of 40P. Tebuthiuron is also available in a prepack with trifluralin as Spike-Treflan 6G. This product offers additional grass control and is applied at rates from 100 to 200 pounds per acre.

Diuron (Karmex) is an 80 percent DF. The rate is 10 to 60 pounds per acre. It is sometimes mixed with bromacil (see **Bromacil + diuron**).

Dichlobenil (Casoron, Norosac, and Barrier) is available as a 50 percent WP and as 4 percent granules. It is used more commonly for nursery weed control than for total vegetation control. The rate is 10 to 40 pounds per acre of the 50 WP.

Sulfometuron (Oust) is a 75 percent DG that is labeled for preemergence and postemergence application to young weeds. The rate is 1 to 12 ounces per acre.

Imazapyr (Arsenal, Chopper) is formulated as a 2-pound acid equivalent-per-gallon aqueous solution (Arsenal, Chopper 2S) or a 3 percent solution (Chopper RTU). Imazapyr is taken up by both foliage and roots and translocated throughout plants. It controls annual and perennial grasses and broadleaves and, at the higher rates, brush species. Labeled rates of the liquid formulations range from 2 to 6 pints per acre. Imazapyr can be applied preemergence or postemergence, but postemergence application is the method of choice, especially to control perennials. Imazapyr usually provides residual soil activity after a postemergence application. Prevent drift to desirable plants. Do not apply Arsenal or Chopper to irrigation ditches, and do not allow runoff to cropland. Imazapyr is corrosive to mild steel, brass, and copper.

Herbicides for Short-Term Control

Amitrole (Amizol, Amitrol-T) is a translocated herbicide that is especially effective on poison ivy, Canada thistle, and perennial grasses such as quackgrass. Amizol is a 90 percent soluble powder that is applied at a rate of 2 to 5 pounds per acre in 50 to 100 gallons of water. Amitrole plus ammonium thiocyanate is available as Amitrol-T in a 2-pound-per-gallon liquid. The application rate is 1 to 4 gallons per acre. Amizol and Amitrol-T are restricted-use pesticides. (Amitrole plus simazine is available as Amizine; see the preceding section, "Herbicides for Long-Term Control").

MSMA is available as Daconate 6, Bueno 6, and Broadside, which are 6-pound-per-gallon liquids with a surfactant included. It is used for perennial grass control at 0.5 to 1.5 gallons per acre. More than one application may be necessary.

DSMA is available as a liquid (DSMA Liquid). It can be used for spot treatment of johnsongrass. The rate is 1 to 2 gallons per acre.

Paraquat (Gramoxone Extra) is a contact herbicide with no residual activity. Gramoxone Extra is a 2.5-pound-per-gallon formulation, labeled at 2 to 3 pints per acre. The volume of water should be adjusted for the amount of vegetation. Paraquat requires the addition of a surfactant. Paraquat is restricted to use by certified applicators.

Glyphosate (Roundup) is a 4-pound-per-gallon translocated herbicide that is nonpersistent. Unlike paraquat, it will translocate to control perennial weeds. The rate is 1 to 5 quarts per acre.

Sulfosate (Touchdown) is a 6-pound-per-gallon translocated herbicide. It is nonpersistent and requires the addition of a nonionic surfactant. It will control annual and perennial grass and broadleaf weeds. The label rate ranges from 0.66 to 5.33 pints per acre.

Long-Term Residual Control: Spray Applications

Many of these chemicals are wettable powders

(WP) and will require thorough agitation before application. A rate range is given to account for different soils and the different types of weeds to be controlled. Initial applications are often made at the higher rate, with subsequent treatments at the lower rate. It is not always prudent to try to achieve control for more than one season with one application. Instead, use a lower rate and reapply annually. See Table 1 for guidelines to the appropriate rate.

Long-Term Residual Control: Granular or Pellet Application

Granules are convenient to use for spot treatments or applications to small areas. Many granules are made with a sodium chlorate-borate base. Application rates for some granular herbicides are given below.

Herbicide	Pounds per 1,000 sq ft
Arsenal 5G	4.6
Casoron-10P	5 to 10
Pramitol 5PS	5 to 20
Spike 20P	0.1 to 0.7
Spike 40P	0.05 to 0.35

Herbicides for Broadleaf Weed and Brush Control

Dicamba (Banvel) is available as a 4-pound-per-gallon formulation. The rate is 1 to 4 quarts per acre. Formulated mixtures with other herbicides are also available. Banvel presents a drift hazard to nearby soybeans, tomatoes, and other broadleaf plants. Weedmaster is a premix of dicamba plus 2,4-D to give broader spectrum control than with either herbicide alone.

Picloram (Tordon) is a broadleaf weed and woody plant herbicide that does not affect grass species. Picloram is formulated as liquid Tordon K (2 lb/gal); Tordon 101 Mixture, Tordon RTU, and Pathway (mixtures of picloram and 2,4-D); and Access (mixture of picloram and triclopyr esters). Tordon K and Tordon 101 Mixture are designed for application to foliage and stems, often in combination with triclopyr for maximum weed and brush control. Access herbicide is formulated for basal-bark applications. Picloram should not be used in soils of rapid permeability and high water table. Tordon K, Tordon 101 Mixture, and Access are restricted for use by certified applicators only. RTU and Pathway, which are premixed and labeled for cut-surface application only, are general-use herbicides.

2,4-D is a broadleaf herbicide with little soil activity. Amine formulations present less hazard to nearby sensitive plants than esters because amines volatilize at higher temperatures. The common formulation is a 3.8-pound-per-gallon liquid.

Dichlorprop or **2,4-DP** (Weedone 2,4-DP) gives better control of some woody plants than 2,4-D. Commercial mixtures of dichlorprop plus 2,4-D (Weedone 170 and Weedone CB) are available for broader spectrum control. Acme Super Brush Killer is a combination of 2,4-DP, 2,4-D, and dicamba for general brush and broadleaf weed control.

Bromacil (Hyvar X or Hyvar X-L) is a 2-pound-per-gallon liquid for basal spraying of brush. A 10 percent pellet (HABCO-10B) is also available.

Fosamine (Krenite S) is available as a 4-pound-per-gallon formulation. When Krenite S is applied within 2 months of autumn leaf discoloration, no symptoms are evident until the following spring, when the plants fail to refoliate. Because Krenite S does not translocate, it can be used for chemical trimming. The rate is 1.34 to 3 gallons per acre.

Triclopyr (Garlon 4, Garlon 3A) is available in 3- or 4-pound-per-gallon formulations, in a formulated mix with 2,4-D (Crossbow), and in a mix with picloram (Access) for basal-bark applications. Triclopyr is a broad-spectrum broadleaf and brush herbicide with no activity in grasses when used at recommended rates. It can be applied in foliar, basal-bark, or cut-surface applications to control many trees, brush species, and herbaceous broadleaf plants.

Bromoxynil (Buctril 2EC) has contact activity against herbaceous broadleaf weeds. The product is toxic to fish and wildlife, so use it cautiously.

Chlorsulfuron (Telar) is a 75 percent DG that is most effective when applied postemergence, but it is also labeled for preemergence application. The rate is 1/4 to 3 ounces per acre. Telar controls a broad spectrum of herbaceous broadleaf plants.

Metsulfuron (Escort 60DF) gives broad-spectrum control of herbaceous and woody broadleaf plants. It may injure certain grasses at high rates of application. An application of Escort can be made anytime from one-half leaf stage in the spring until just before autumn coloration. Plants are most suspectible when the application is made during warm, moist weather.

Control of Broadleaf Weeds

Broadleaf weeds are often best controlled with foliar applications. Deep-rooted perennials can usually be controlled best when they are at the early bud or bloom stage. Some of the herbicides listed in Table 2

Table 1. Spray Applications for Long-Term Weed Control

Herbicide	Rate of formulation/acre		
	Annuals	Shallow perennials	Deep perennials
Arsenal 2S	2 to 4 pt	1 to 6 pt	4 to 6 pt
Asulox (3.3 lb/gal)	1 to 2 gal	1 to 2 gal	...
Casoron (50W)	8 to 12 lb	12 to 25 lb	25 to 40 lb
Hyvar X (80W)	3 to 6 lb	7 to 15 lb	7 to 15 lb
Hyvar X-L (2 lb/gal)	1.5 to 3 gal	3 to 6 gal	6 to 12 gal
Karmex (80W or 80DF)	5 to 15 lb	5 to 15 lb	5 to 15 lb
Krovar I (80DF)	4 to 6 lb	7 to 18 lb	19 to 40 lb
Oust (75WDG)*	3 to 5 oz	6 to 8 oz	6 to 8 oz
Pramitol 25E (2 lb/gal)	5 to 7.5 gal	7.5 to 10 gal	10 gal
Sodium chlorate	300 to 500 lb	500 to 750 lb	750 to 1,300 lb
Spike (80W)	5 to 7.5 lb	2.5 to 5 lb	3.75 to 7.5 lb
Surflan AS (4 lb/gal)	3 to 6 qt	3 to 6 qt	3 to 6 qt
Velpar (90WSP)	2 to 5 lb	6 to 12 lb	...
Velpar L or RP (2 lb/gal WDL)	1 to 2.5 gal	3 to 6 gal	...

*Note that the rate of formulation is in ounces per acre.

Table 2. Herbicides for Broadleaf Weed Control

Herbicide	Rate of formulation/acre	
	Annuals and shallow perennials	Deep perennials
2,4-D	1 to 2 qt	2 to 4 qt
Acme Super Brush Killer (2,4-D + 2,4-DP + dicamba)	1 to 2 qt	2 to 4 qt
Banvel (dicamba)	0.5 to 1 qt	1 to 4 qt
Buctril (bromoxynil)	1 to 2 pt	1 to 2 pt
Crossbow (triclopyr + 2,4-D)	1 to 2 qt	2 qt
Escort (metsulfuron)	0.33 to 0.5 oz	0.5 to 2 oz
Garlon 3A (triclopyr)	2 to 3 qt	3 to 6 qt
Garlon 4 (triclopyr)	1 to 2 qt	2 to 4 qt
Roundup (glyphosate)	0.5 to 3 qt	3 to 5 qt
Telar (chlorsulfuron)	0.25 to 1 oz	1 to 3 oz
Tordon 101 Mixture (picloram + 2,4-D)	2 to 3 qt	1 to 3 gal
Tordon K (picloram)	0.5 to 2 qt	2 to 4 qt
Touchdown (sulfosate)	0.66 to 4 pt	4 to 5.35 pt
Transline (clopyralid)	0.33 to 0.5 pt	0.67 to 1.33 pt
Weedmaster (2,4-D + dicamba)	0.5 to 4 pt	4 to 6 pt

can move through the air and damage nearby desirable trees, shrubs, and broadleaf plants. Some of the herbicides are mobile in the soil and can damage desirable broadleaves if applied to the soil near their roots. See Table 2 for guidelines to the appropriate rate.

Control of Undesirable Woody Plants

Most of the herbicides used to control woody plants are applied to the foliage, but many of them can also be applied as basal-bark treatments if the woody plants have stems that are smaller than 5 inches in diameter or as cut-surface (frilled) treatments if the plants are larger. Basal-bark treatments are usually applied in fuel oil. Application can be made throughout the year, even during the dormant season. Cut-surface treatments can also be made throughout the year, but the herbicides should be applied to the cut surface within 2 to 3 hours of cutting. Foliar treatments are usually applied in the spring as soon as the leaves of brush or trees have fully expanded. See Chapter 13, "Brush Control in Illinois," for more detailed information on method of application. See Table 3 for guidelines to the appropriate rate and method of application.

Weedy Grass Control

Weedy grasses can be controlled with the herbicides listed below. The use of a surfactant is labeled for some of these herbicides. (Before using, read the label of a product carefully; some of the products listed below are nonselective and will kill broadleaves as well as grasses.)

	Rate of formulation/acre	
Herbicide	Annuals	Perennials
Asulox	1 to 2 gal	1 to 2 gal
Amitrol-T	1 gal	2 to 3 gal
Daconate (MSMA)	2 to 3 qt	3 to 5 qt
DSMA	1 to 2 qt	2 to 4 qt
Horizon	19 to 45 fl oz	32 to 45 fl oz
Horizon 2000	7 to 8 fl oz	9 fl oz
Roundup	0.38 to 2 qt	1 to 5 qt
Touchdown	0.66 to 2.66 pt	1.33 to 5.35 pt

Contact Weed Control

Contact herbicides, such as Gramoxone Extra, kill only the plant tissue with which they come in contact; therefore, adequate spray volume is needed for thorough coverage of the foliage. A surfactant is required, as indicated by the Gramoxone Extra label, to help improve foliar coverage. The Gramoxone Extra rate is 0.67 to 1.67 quarts per acre.

Comments

Whenever possible, use desirable plants to compete with and replace undesirable plants. For some areas, mechanical control may be the most practical and appropriate method.

Availability, formulations, trade names, and federal clearance for the use of herbicides change occasionally.

Always refer to the most recent product label for precautions, directions, and application rates. Use herbicides appropriately to avoid injury to yourself and others, to desirable nontarget vegetation, and to the environment.

Table 3. Herbicides for Woody Plant Control

Herbicide	Method of application	Rate of formulation
Access (picloram + triclopyr)	Basal-bark	1 to 2 gal/100 gal spray mixture*
Acme Super Brush Killer (2,4-D+ 2,4-DP, + dicamba)	Foliar, basal-bark, cut-surface	0.5 to 1 gal/100 gal water for foliar; 1 gal/25 gal diesel fuel for basal-bark or cut-surface
Arsenal 2S (imazapyr)	Foliar or cut-surface	2 to 3 qt/A
Banvel (4 lb/gal dicamba)	Foliar	2 to 4 qt/A
Chopper (2 lb/gal imazapyr)	Basal-bark or cut-surface	Wet cambium thoroughly
Chopper RTU (3% imazapyr)	Basal-bark or cut-surface	8 to 12 oz/gal; wet cambium thoroughly
Crossbow (triclopyr + 2,4-D)	Foliar	4 to 6 qt/A
Escort (metsulfuron)	Foliar	0.33 to 2 oz/A
Garlon 3A (44.4 percent triclopyr)	Foliar or cut-surface	2 to 3 gal/A
Garlon 4 (61.6 percent triclopyr)	Foliar or basal-bark	4 to 8 qt/A*
Krenite (4 lb/gal)	Foliar	1.5 to 3 gal/A
Pathway (picloram + 2,4-D)	Cut-surface	Wet cambium thoroughly
Roundup (glyphosate)	Foliar	2 to 5 qt/A
	Spot treatment	1 to 2 percent solution
Tordon 101 Mixture (picloram + 2,4-D)	Foliar or cut-surface	1 to 4 gal/A
Tordon K (picloram)	Foliar or soil	1 to 2 qt/A
Tordon RTU (picloram + 2,4-D)	Cut-surface	Wet cambium thoroughly
Weedone 170 (2,4-D + dicloprop)	Foliar	4 to 6 qt/100 gal spray
	Basal-bark or cut-surface	3 to 4 gal/100 gal spray
2,4-D ester	Foliar or basal-bark	2 to 4 qt/A

*20 to 30 percent in carrier for low-volume application.

15

Controlling Aquatic Vegetation

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Aquatic vegetation, at moderate growth levels, is useful because it produces oxygen, food, and cover for fish and other aquatic organisms. However, in overabundance, aquatic plants can become weedy; they can crowd out desirable plants, adversely affect other aquatic life, and interfere with human uses of water. The use and management objectives for a particular body of water determine to a large extent the need for management and/or control of aquatic plants.

As with any type of weed control, aquatic or terrestrial, identification is the first step to developing a sound control program. In assessing aquatic weed problems, all traditional methods of control should be evaluated for short- and long-term effectiveness, applicability to the management situation, level of plant control desired, and cost.

Preventive control is achieved through nutrient control or habitat manipulation. Mechanical control physically removes the vegetation. Cultural control includes the use of dyes, plastics, or aeration techniques. Biological control using the triploid carp has been extremely successful in some instances. After all these control measures have been exhausted, chemical methods can be used to control weeds.

Selecting a Herbicide

When choosing a herbicide, consider these essential items. The weed or weeds must be properly identified. Most aquatic herbicides will control only certain plant types indicated on the pesticide label. Table 1 lists the aquatic herbicides labeled for the control of commonly occurring aquatic weeds in Illinois.

Consider the uses of the water that is to be treated. Most aquatic herbicides restrict use of the water until the herbicide has been degraded, inactivated, or dissipated. Table 2 lists aquatic herbicides and their use restrictions. In addition, check the pesticide label for use restrictions and length of restricted use. This may be a major consideration, depending on how the water is to be used.

Timing of the treatment is also important when determining which herbicide to use. Most aquatic herbicides should be applied in mid- to late spring or early summer when plants are young, actively growing, and most susceptible to herbicides. An exception is preemergence herbicides such as dichlobenil. If you wait until late summer to treat, you run a serious risk of killing fish. By that time, the vegetation is usually extensive and thick and the water is warm and still. Killing all vegetation at once under these conditions could seriously deplete the water of its oxygen and cause a fish kill.

Water temperature affects the efficacy of some herbicides. Herbicides are not effective on aquatic weeds when the water is too cold. The water should be in the upper 60's; these temperatures usually occur from late April to early June. Therefore, you should apply herbicide as soon as the plants are up and actively growing and the temperature is right. Follow label recommendations.

Method of application may affect your choice if a certain type of equipment is needed for treatment to be effective. Consult labels for specific instructions on how to treat the area.

You should also consider the probability of having to retreat, even within the same year; a herbicide's toxicity to fish; the potential for damage to shoreline vegetation; and the cost of an appropriate herbicide for a specific management program.

Herbicides Labelled for Use in Aquatic Areas

Only a handful of herbicides are labeled for use in aquatic areas. The label must specifically state that the herbicide is intended for aquatic use. Applying unlabeled products violates federal regulations. The products labeled for use in aquatic areas, their basic manufacturer, and their formulation, are listed in Table 3. Please note that simazine and dalapon are no longer labeled for aquatic areas. The manufacturer has vol-

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

Table 1. Aquatic Herbicides Labeled for the Control of Commonly Occurring Aquatic Weeds in Illinois

Aquatic weed										
Common name	Scientific name	Aquathol	Komeen	Coppers	Casoron	Diquat	Hydrothol	Sonar	Glyphosate	2,4-D
ALGAE										
Filamentous algae	many	NL	NL	L	NL	L	L	NL	NL	NL
Microscopic algae	many	NL	NL	L	NL	NL	NL	NL	NL	NL
Chara	*Chara*	NL	NL	L	L	NL	L	NL	NL	NL
FLOWERING PLANTS										
Submersed										
American elodea	*Elodea canadensis*	NL	NL	NL	L	L	L	L	NL	NL
Bladderwort	*Utricularia vulgaris*	NL	NL	NL	L	L	NL	L	NL	C
Brittle naiad	*Najas minor*	L	NL	NL	L	L	L	L	NL	NL
Buttercup	*Ranunculus* spp.	NL	NL	NL	NL	NL	NL	NL	R	C
Cabomba	*Cabomba caroliniana*	NL	NL	NL	NL	NL	PC	NL	NL	NL
Clasping-leaf pondweed	*Potamogeton richardsonii*	NL	NL	NL	L	L	L	L	NL	NL
Coontail	*Ceratophyllum demersum*	L	NL	NL	L	L	L	L	NL	C
Curly-leaf pondweed	*Potamogeton crispus*	L	NL	NL	L	L	L	L	NL	NL
Eel grass	*Vallisneria americana*	NL	NL	NL	L	NL	L	PC	NL	NL
Flat-stemmed pondweed	*Potamogeton zosteriformis*	L	NL	NL	L	L	L	L	NL	NL
Horned pondweed	*Zannichellia palustris*	L	NL	NL	NL	NL	L	NL	NL	NL
Leafy pondweed	*Potamogeton foliosus*	NL	NL	NL	L	L	L	L	NL	NL
Sago pondweed	*Potamogeton pectinatus*	L	NL	NL	L	L	L	L	NL	NL
Small pondweed	*Potamogeton pusillus*	L	NL	NL	L	L	L	L	NL	NL
Southern naiad	*Najas guadalupensis*	NL	L	NL	L	L	L	L	NL	NL
Water milfoil	*Myriophyllum* spp.	L	NL	NL	L	L	L	L	NL	C
Waterstargrass	*Heteranthera dubia*	L	NL	NL	NL	NL	NL	NL	NL	C
Widgeongrass	*Ruppia maritima*	NL	NL	NL	L	NL	NL	NL	NL	NL
Free-floating										
Common duckweed	*Lemna minor*	NL	NL	NL	NL	L	NL	L	NL	NL
Star duckweed	*Lemna trisulca*	NL	NL	NL	NL	L	NL	NL	NL	NL
Water pennywort	*Hydrocotyle* spp.	NL	NL	NL	L	L	NL	NL	NL	C
Rooted floating										
American lotus	*Nelumbo lutea*	NL	NL	NL	NL	NL	NL	PC	L	C
American pondweed	*Potamogeton nodosus*	L	NL	NL	L	L	L	L	NL	NL
Floating pondweed	*Potamogeton natans*	L	NL	NL	L	L	L	L	NL	NL
Illinois pondweed	*Potamogeton illinoensis*	NL	NL	NL	L	L	L	L	NL	NL
Largeleaf pondweed	*Potamogeton amplifolius*	L	NL	NL	L	L	L	L	NL	NL
Spatterdock	*Nuphar advena*	NL	NL	NL	L	NL	NL	L	L	C
Waterpurslane	*Ludwigia palustris*	NL	NL	NL	NL	NL	NL	L	NL	NL
Water lily	*Nymphaea* spp.	NL	NL	NL	L	NL	NL	L	NL	C
Watershield	*Brasenia schreberi*	NL	NL	NL	NL	NL	NL	NL	NL	C
Waterthread pondweed	*Potamogeton diversifolius*	L	NL	NL	L	L	L	L	NL	NL

Table 1. Aquatic Herbicides Labeled for the Control of Commonly Occurring Aquatic Weeds in Illinois (cont.)

Aquatic Weed										
Common name	Scientific name	Aquathol	Komeen	Coppers	Casoron	Diquat	Hydrothol	Sonar	Glyphosate	2,4-D
Emergent										
Arrowhead	*Sagittaria* spp.	NL	NL	NL	NL	NL	NL	PC	NL	C
Bulrush	*Scirpus* spp.	NL	NL	NL	NL	NL	NL	PC	L	C
Bur reed	*Sparganium* spp.	L	NL	NL	NL	NL	NL	NL	NL	C
Cattail	*Typha spp.*	NL	NL	NL	L	L	NL	PC	L	NL
Creeping water primrose	*Jussiaea repens*	NL	NL	NL	L	NL	NL	PC	L	C
Pickerelweed	*Pontederia* spp.	NL	NL	NL	NL	NL	NL	NL	NL	C
Purple loosestrife	*Lythrum salicaria*	NL	NL	NL	L	NL	NL	NL	L	NL
Spikerush	*Eleocharis spp.*	NL	NL	NL	NL	NL	NL	PC	NL	NL
Water smartweed	*Polygonum* spp.	NL	NL	NL	NL	NL	NL	PC	L	C
Willow	*Salix* spp.	NL	NL	NL	NL	NL	NL	NL	L	C

SOURCE: Information has been collected from chemical manufacturer labels. Although some products could control more species, only the species listed on the label are included.
NL = not labeled for control of this species; L = Labeled for control of this species; R = Rodeo label only;
C = check labels for specific species listed (each 2,4-D product is different); PC = Labeled for partial control only of this species.

Table 2. Aquatic Herbicides and Their Use Restrictions (in days)

	Human			Animal	Irrigation
Herbicide	Drinking	Swimming	Fish consumption	Drinking	Turf, forage, and food crops
Aquathol (granular)	7	1	3	7	7
Aquathol (liquid)	7 to 25	1	3	7 to 25	7 to 25
Copper chelate/sulfate	0	0	0	0	0
Casoron 10G	TW	TW	90	TW	TW
Diquat/Weedtrine-D	14	1	0	14	14
Hydrothol (granular)	7 to 25	7 to 25	3	7 to 25	7 to 25
Hydrothol (liquid)	7 to 25	7 to 25	3	7 to 25	7 to 25
Sonar*	1	0	0	0	7 to 30
Rodeo/Pondmaster*	1	0	0	0	0
2,4-D - Aqua-Kleen	TW	TW	TW	TW	TW
Solution	TW	TW	TW	TW	TW
Weedar 64	TW	TW	TW	TW	TW
Weedtrine II	TW	TW	TW	TW	TW

TW = Do not use treated water for domestic purposes, livestock watering, or for irrigation.
*Do not apply this product within 1/4 to 1/2 mile of potable water intake.

untarily dropped aquatic uses for Simazine or Aquazine due to the prohibitive costs involved in reregistering the product. All uses of Dalapon (Dowpon) have been discontinued in the United States.

Those chemicals labeled for use in aquatic areas are described in the following paragraphs. Ranges of rates are given where possible. Rates for all products vary according to product formulation, species present, and stage of plant growth. Follow label directions carefully in calculating dosage and don't overdo it. Most aquatic herbicide labels give dosages on the basis of acre-feet (volume measurement). Acre-feet measurements are calculated by multiplying surface area by the average depth. For example, a pond with a surface acreage of 1/2 acre and an average depth of 4 feet contains (4 feet x 1/2 acre) 2 acre-feet. The herbicide label will then tell you the amount of chemical to apply per acre-foot.

Copper sulfate is used strictly for algae (including Chara) control. It has little or no effect on flowering plants at normal use rates. The copper is formulated as copper sulfate pentahydrate (CSP). It may be used at a maximum dosage of 4 parts per million (ppm) CSP, but the normal use rate is 1 ppm CSP, or 2.7 pounds of CSP per acre-foot of water. There are no restrictions on the use of the water following treatment. Copper sulfate is a contact herbicide; therefore, algae must be directly exposed to the compound, and it is essential to have good distribution in the water where the plants are growing. The granular form is best applied by putting it in a burlap sack and towing it by boat around the pond until it is dissolved. The powder form is best used by dissolving it in water and spraying it onto the algae mats and into the water.

Copper chelates (copper held in organic molecules) are formulations that prevent copper from precipitating from the water. Copper chelates have somewhat longer-lasting results and are slightly less toxic to fish (except trout) than copper sulfate. Copper chelates are used primarily to control algae, but some submersed flowering plants are also susceptible. Like copper sulfate, the copper chelates are contact materials and have no water use restrictions other than toxicity to trout. Copper chelates are formulated as liquids, granules, or powders. Rates range from 0.2 to 1.0 ppm copper per acre–foot. They can be used as a spot treatment or mixed with water and sprayed or injected into the infested area as a broadcast treatment.

Endothall is a contact herbicide and requires reasonably good distribution to be effective. Restrictions on the use of treated water range from waiting 24 hours for swimming to 7 to 25 days for irrigation. Endothall is available in two salt forms: amine salt (Hydrothal) and dipotassium salt (Aquathol). Hydrothol liquid is recommended for use only by commercial applicators. It can cause fish kills and severe skin burns. The Aquathol liquid should be used with caution, but it is much safer than Hydrothol liquid where fish are present. Spray or inject liquid-water mix into infested areas, or use as spot treatments. Rates vary from 0.05 to 5.0 ppm per acre-foot.

Diquat is a contact herbicide; therefore, optimal activity depends on direct contact with the plant, either by dispersing the herbicide completely in the water or by spraying it directly on the plant. The mix can be used as a spot treatment. Spray is used for duckweed control. Restrictions on the use of treated water range from 24 hours to 14 days, depending on the activity. Do not use diquat in muddy water or on silt-covered plants as the chemical will be deactivated, resulting in poor control. Diquat is often used as a tank mix with the liquid forms of copper chelates and the dipotassium salt of endothall to provide a broad spectrum of control for aquatic weeds. Rates vary from 0.5 to 10 gallons per surface acre.

Dichlobenil is a granular, soil-active, systemic herbicide that provides preemergence aquatic weed control. Because it works before the weeds germinate, it should be applied to the water or to exposed sediments in early spring. The granules settle in the sediments where they inhibit new shoot growth as the plants start to grow. There is a 90-day restriction on the use of fish from treated water for food or feed. Dichlobenil should not be applied to water intended for irrigation, livestock watering, or human consumption. Rates vary from 40 to 150 pounds per surface acre.

2,4-D gives selective control of terrestrial broadleaf plants. The liquid formulation is used mainly for foliar applications to emergent and floating plants or large areas of certain submersed species. The granular ester formulation is used for spot treatments and to control low-growing, submersed plants. Restrictions vary but, in general, the herbicide should not be used in water intended for irrigation, domestic use, or watering dairy herds. Fish toxicity varies according to formulation. Rates range from 100 to 200 pounds per acre or 100 to 400 gallons per acre.

Fluridone is a broad spectrum-herbicide that controls or reduces the activity of a wide variety of submersed, emergent, and floating plants and shoreline grasses. It does not control algae. Fluridone has been shown to give control for a year or longer. For best results, it should be applied during early stages of rapid weed growth. Symptoms are visible 7 to 10 days

Table 3. Common and Trade Names, Manufacturers, and Formulations of Aquatic Herbicides

Common name	Trade name	Basic manufacturer	Formulation
2,4-D (amine)	Solution	Riverdale	96.9% water soluble bag
2,4-D (amine)	Weedar 64	Rhone-Poulenc Ag Co.	3.8 lb/gal liquid
2,4-D (ester)	Aqua-Kleen	Rhone-Poulenc Ag Co.	27.6% granular
2,4-D (ester)	Weedtrine-II	Applied Biochemists, Inc.	28.9% granular
copper sulfate	many	many	many
copper-ethanolamine	Cutrine-Plus	Applied Biochemists, Inc.	0.909 lb/gal liquid
copper-ethanolamine	Cutrine-Plus	Applied Biochemists, Inc.	3.7% granular
copper-ethylenediamine	Komeen	Griffin Corp.	0.8 lb/gal liquid
copper-triethanolamine	K-Tea	Griffin Corp.	0.8 lb/gal liquid
copper-triethanolamine	Algae-Rhap	CP Chemicals	0.74 lb/gal liquid
copper-triethanolamine	Lescocide-Plus	Lesco	3.7% granular or 0.909 lb/gal liquid
dichlobenil	Casoron 10G	Uniroyal Chemical	10% granular
diquat	Diquat	Valent USA Corp.	2 lb/gal liquid
diquat	Weedtrine-D	Applied Biochemists, Inc.	0.746 lb/gal liquid
dye	Aquashade	Aquashade, Inc.	liquid
endothall (amine)	Hydrothol 191	Atochem North America, Inc.	2 lb/gal liquid
endothall (amine)	Hydrothol 191	Atochem North America, Inc.	11.2% granular
endothall (dipotassium)	Aquathol	Atochem North America, Inc.	10.0% granular
endothall (dipotassium)	Aquathol K	Atochem North America, Inc.	4.23 lb/gal liquid
fluridone	Sonar A.S., 5P, or SRP	DowElanco	4 lb/gal liquid or 5% pellet
glyphosate	Pondmaster	Monsanto Agricultural Co.	4 lb/gal liquid
glyphosate	Rodeo	Monsanto Agricultural Co.	5.4 lb/gal liquid

after treatment, but 30 to 90 days are needed for complete weed removal. Fluridone is not recommended for spot treatments or in areas where dilution or water movement will not allow sufficient contact time. Irrigation is restricted from 7 to 30 days after application. Fluridone should not be applied within 1/4 mile of a potable water intake. Neither should it be applied in water or near a shoreline where the roots of desirable trees and shrubs extend as injury to those trees and shrubs might occur. Rates vary from 0.75 to 4 quarts or 15 to 80 pounds per surface acre.

Glyphosate plus an added surfactant (Pondmaster is premixed with a surfactant) is labeled for control of rooted floating plants and emergent plants. Glyphosate moves systemically through the plant from the point of foliage contact into the root system; thus it will not control plants that are completely submersed or have most of their foliage underwater. Uptake occurs within 6 hours after treatment with wilting and yellowing of plants occurring 2 to 7 days after treatment. The best time to treat is when plants are matured or as specifically recommended on the label. Glyphosate should not be used within 1/4 to 1/2 mile of a potable water intake. Rates vary from 1-1/2 to 7-1/2 pints of product per acre or 3/4 to 1-1/2 percent in a spot spray solution.

When developing a weed control program, always consider the possible environmental effects associated with the control measure. Treatment of heavy infestations in the summer may cause oxygen depletion and fish kill. Follow label recommendations and make partial treatments during these times at 2- to 3-week intervals. In addition to herbicides, possible sources of toxicity in aquatic weed control include adjuvants, surfactants, wetting agents, and inverting oils. Weed control programs will also change the physical habitat of an aquatic area.

In summary, when choosing an aquatic weed control program, identify the weed problem and consider the use of the site before choosing a control method. If herbicides are chosen, use them at the recommended rates, apply them properly, and follow all use restrictions. Improper application rates, incorrect formulations, or faulty application may cause a fish kill or seriously alter the food chain, slowing the growth rate of fish.

Pesticide Information

Pesticide Information

16 Application Equipment and Calibration References

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Nozzle Nomenclature

There are many types of spray nozzles available, each providing different flow rates, spray angles, droplet sizes and spray patterns. Some commonly used nozzle types are shown in Figures 1 and 2. Nozzles that produce flat-fan spray patterns are in Figure 1 and nozzles that produce cone spray patterns are in Figure 2. Table 1 can be used as a guideline for selecting the proper nozzle type for each application. Nozzle manufacturers often code spray nozzles to indicate specific spray characteristics. The tip number may indicate the nozzle type, flow rate and spray fan angle. Other characteristics are identified with letters representing specific operating conditions. Table 2 lists the nomenclature for various types of commercially available nozzles. Many nozzles are now color coded for ease of identification and Table 3 gives the color codes used by two nozzle manufacturers.

Sprayer Calibration Guidelines

Variables Affecting Application Rate

Three variables affect the amount of spray mixture applied per acre: (1) the nozzle flow rate; (2) the ground speed of the sprayer; and (3) the effective sprayed width per nozzle.

The gallons of spray applied per acre can be determined from the three variables in the following equation:

$$GPA = \frac{GPM \times 5940}{MPH \times W}$$

Where:

GPA = spray applied, in gallons per acre

GPM = output per nozzle, in gallons per minute

MPH = ground speed, in miles per hour

W = effective sprayed width per nozzle, in inches

For broadcast spraying, W = the nozzle spacing.

For band spraying, W = the band width.

For row crop applications (such as spraying from drop pipes or directed spraying), W = row spacing (or band width) divided by the number of nozzles per row (or band).

5940 = a constant to convert gallons per minute, miles per hour, and inches to gallons per acre.

Selecting the Proper Nozzle Tip

The proper size of nozzle can be selected by determining the required flow rate from each nozzle at a selected application rate (GPA), ground speed (MPH), and effective sprayed width (W) in inches per nozzle. The required flow rate per nozzle can be determined from the following equation:

$$GPM = \frac{GPA \times MPH \times W}{5940}$$

Select a nozzle that will give the required flow rate when the nozzle is operated within the recommended pressure range. Tables have been included at the end of the chapter that list the flow rates for commonly used nozzles that are available from several manufacturers (Tables 11 through 19).

Calibrating the Sprayer

Install the selected nozzle tips in the sprayer. Determine the flow rate for each nozzle in ounces per minute (OPM) from the following equation:

$$OPM = GPM \times 128 \text{ (1 gallon = 128 ounces)}$$

Measure the flow rate using a flow meter or collect the output from a nozzle using a container marked in ounces. Adjust the pressure until the required GPM or OPM is collected. Check the nozzle flow rate frequently. Adjust the pressure to compensate for small

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changes in nozzle output resulting from nozzle wear. Replace the nozzle tips and recalibrate when the output has changed 10 percent or more from that of a new nozzle, or when the pattern has become uneven.

Flow Rate

Nozzle flow rate varies with spraying pressure. The relationship between GPM and pressure is as follows:

$$\frac{GPM_1}{GPM_2} = \frac{\sqrt{PSI_1}}{\sqrt{PSI_2}}$$

With the above relationship, doubling the flow through the nozzle requires increasing the pressure four times. The above equation can be used to determine nozzle flow rates achieved at various pressures.

EXAMPLE:

If a certain nozzle has a flow rate of 0.6 GPM at a pressure of 40 PSI, what would the flow rate be if operated at 15 PSI?

SOLUTION:

Rearrange the above formula to obtain GPM_2:

$$GPM_2 = \frac{\sqrt{PSI_2}}{\sqrt{PSI_1}} \times GPM_1$$

Solve for the new flow rate:

$$GPM_2 = \frac{\sqrt{15\ PSI}}{\sqrt{40\ PSI}} \times 0.6\ GPM$$

$$GPM_2 = \frac{\sqrt{3.873}}{\sqrt{6.325}} \times 0.6$$

$$GPM_2 = 0.61 \times 0.6 = 0.4$$

Effect of Solution Density on Nozzle Flow Rate

Density is the weight of a solution per unit volume (lb/gal). Specific gravity (SG) is the weight of a solution relative to water, which weighs 8.34 lb/gal. Nozzle flow rate varies inversely with the square root of specific gravity. Conversion factors to compare flow rates of solutions of any known density can be calculated thusly:

$$\text{Conversion factor} = \sqrt{SG}$$

The table below can be used to predict the flow rate from various solutions and to select the proper nozzle size from a nozzle catalog table. Because nozzle tables are based on spraying water, the conversion factors from the table can be multiplied by the desired GPM or GPA to determine the water flow rate for the solution being sprayed. Use the converted GPM or GPA to select the proper nozzle size from the catalog.

EXAMPLE:

$$3\ GPM\ (28\%\ N) \times 1.13 = 3.39\ (water)$$

If the flow rate (GPM) or application rate (GPA) of water is known, the GPM or GPA of a solution can be predicted by dividing the flow or application rate by the conversion factor.

EXAMPLE:

$$20\ GPA\ (water) \div 1.13 = 17.7\ GPA\ (28\%N)$$

Specific Gravity and Conversion Factor for Selected Solution Weights
This table is based on theoretical solution densities only and may vary in actual practice because of differing solution characteristics. Applies to flood nozzles but not Raindrop nozzles.

Weight of solution (lb/gal)	Specific gravity	Conversion factor
7.0	0.84	0.92
8.0	0.96	0.98
8.34[a]	1.00	1.00
9.0	1.08	1.04
10.0	1.20	1.10
10.65[b]	1.28	1.13
11.0	1.32	1.15
12.0	1.44	1.20
14.0	1.68	1.30

[a]Water
[b]28% nitrogen

Measuring Ground Speed

To measure ground speed, mark off a distance in the field to be sprayed or in a field with similar surface conditions. Suggested distances are 100 feet for speeds up to 5 miles per hour, 200 feet for speeds from 5 to 10 miles per hour, and at least 300 feet for speeds above 10 miles per hour. At the engine throttle setting and gear used for actual spraying, determine the travel time between the measured stakes. Calculate ground speed using the following table or apply the following formula:

$$\text{Travel speed (MPH)} = \frac{\text{distance (feet)} \times 60}{\text{time (seconds)} \times 88}$$

Time Required to Obtain Various Travel Speeds

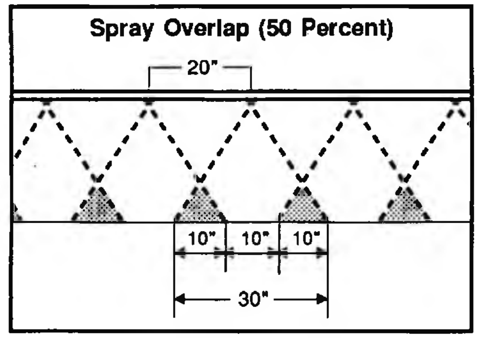
Speed (miles per hour)	Time in seconds required to travel a distance of: 100 ft	200 ft	300 ft
3.0	23	45	68
3.5	20	39	58
4.0	17	34	51
4.5	15	30	45
5.0	14	27	41
6.0		23	34
7.0		19	29
8.0		17	26
9.0		15	23
10.0		14	20
11.0			19
12.0			17
13.0			16
14.0			15
15.0			14

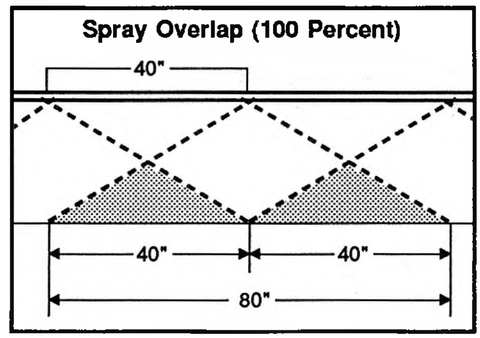
Spray Overlap

For uniform application, each nozzle type must be operated at a spacing and height that provide a specific spray overlap. The overlap may vary from 20 percent to more than 100 percent. The percent overlap or spray coverage is illustrated in the following figure and Table 4 and can be calculated from the following formulas:

$$\text{Percent overlap} = \frac{\text{Spray coverage} - \text{nozzle spacing}}{\text{nozzle spacing}}$$

$$\text{Spray coverage} = (\text{nozzle spacing} \times \text{percent overlap}) + \text{nozzle spacing}$$

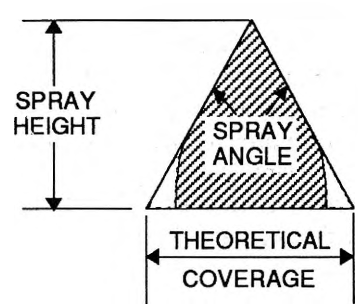


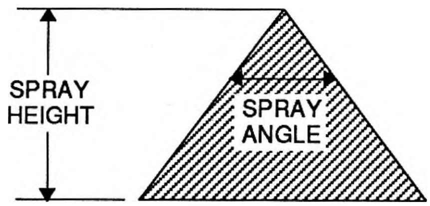


Spray Angle Coverage at Various Heights

Table 5 lists the theoretical coverage of spray patterns as calculated from the included angle of the spray and the distance from the nozzle orifice. These values are based on the assumption that the spray angle remains the same throughout the entire spray distance. In actual practice, the tabulated spray angle does not hold for long spray distances. Adjust the spray height to give proper spray overlap. Following are suggested minimum spray heights.

Spray angle	20-inch spacing	30-inch spacing
65°	22" to 24"	33" to 36"
73°	20" to 22"	29" to 36"
80°	17" to 19"	26" to 28"
110°	10" to 12"	14" to 18"

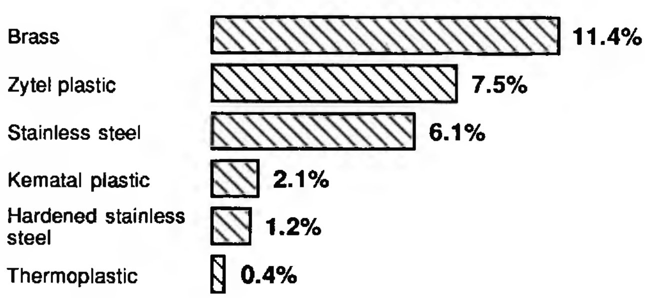




Nozzle Wear

Nozzle tips are available in a variety of materials, including hardened stainless steel, stainless steel, thermoplastics, and brass. Ceramic and hardened stainless steel are the most wear-resistant materials, but are also the most expensive. Stainless steel tips have excellent wear resistance with either corrosive or abrasive materials. Nylon and other synthetic plastics (thermoplastics) are resistant to corrosion and abrasion, but they vary considerably in their wear life, depending on the material used to mold the tips. Brass tips wear rapidly when used to apply abrasive materials such as wettable powders, and they are corroded by some liquid fertilizers.

The following graph shows the percent increase in flow rates after a 40-hour wear test for flat-fan nozzles constructed of various materials.



Techniques for Reducing Spray Drift

When applying pesticides there is always a chance that some will escape from the target area. Although drift cannot be completely eliminated, the use of proper equipment and spraying techniques will maintain drift deposits within acceptable limits. The type of nozzle, pressure, height, and spray volume all affect the off-target movement. The ability to reduce drift is no better than the weakest component in the spraying procedure. A summary of recommended procedures for minimizing spray drift is given in Table 6.

One of the best tools available for minimizing drift damage is the use of drift control additives to increase the spray droplet size. Tests indicate that downwind drift deposits are reduced from 50 to 80 percent with the use of drift control additives. A number of drift control additives are commercially available, but they must be mixed and applied according to label directions in order to be effective. Table 7 is a listing of commonly used drift control additives. They do not eliminate drift, however, and common sense must still remain the primary factor in reducing drift damage.

Pressure Drop Through Spraying Systems

Hoses and fittings must be selected in order to keep the pressure drops within acceptable limits. Tables 8 through 10 give the pressure drop through various sizes of hoses, pipe, and couplings.

Miscellaneous Reference Information

Standard Abbreviations

GPA = gallons per acre
GPM = gallons per minute
GPH = gallons per hour
MPH = miles per hour
OPM = ounces per minute
PSI = pounds per square inch

Volume and Liquid Measures

8 fluid ounces = 1 cup = 236.6 ml

2 cups = 32 tablespoons = 1 pint = 473.1 ml

2 pints = 64 tablespoons = 1 quart = 946.2 ml

8 pints = 4 quarts = 1 gallon

1 gallon = 128 fluid ounces = 3785 ml

Miscellaneous Conversion Equivalents

1 acre = 43,560 square feet = 0.405 hectares

1 hectare = 2.471 acres

1 gallon per acre = 9.35 liters per hectare

1 mile = 5280 feet = 1610 meters = 1.61 kilometers

1 pound per square inch (PSI) = 0.070 kg/cm^2 = 6.895 kPa (kilopascals)

1 pound = .454 kilogram

1 inch = 2.54 centimeters

Metric Conversion Factors

During the next few years, a gradual transition to metric (SI) units is expected in the agricultural industry. To facilitate use of these units, selected metric terms and conversion factors are given in the following table.

Selected Metric Conversion Factors

To measure	Multiply	By	To obtain
Length	inches	25.40	millimeters (mm)
	inches	2.540	centimeters (cm)
	feet	0.3048	meters (m)
	miles	1.609	kilometers (km)
Area	acres	46.7	square meters (m^2)
	acres	0.4047	hectares (ha)
Volume	gallons	3.785	cubic decimeters (dm^3)
	gallons	3.785	liters (L)
	imperial gallons	4.546	liters (L)
Flow rate	gallons/hours (GPH)	3.785	liters/hour (L/h)
	gallons/minute (GPM)	3.785	liters/minute (L/min)
Appl. rate	gallons/acre (GPA)	9.353	liters/hectare (L/ha)
Pressure	pounds/in^2 (PSI)	6.895	kilopascals (kPa)
Speed	miles/hour (MPH)	1.609	kilometers/hour (km/h)

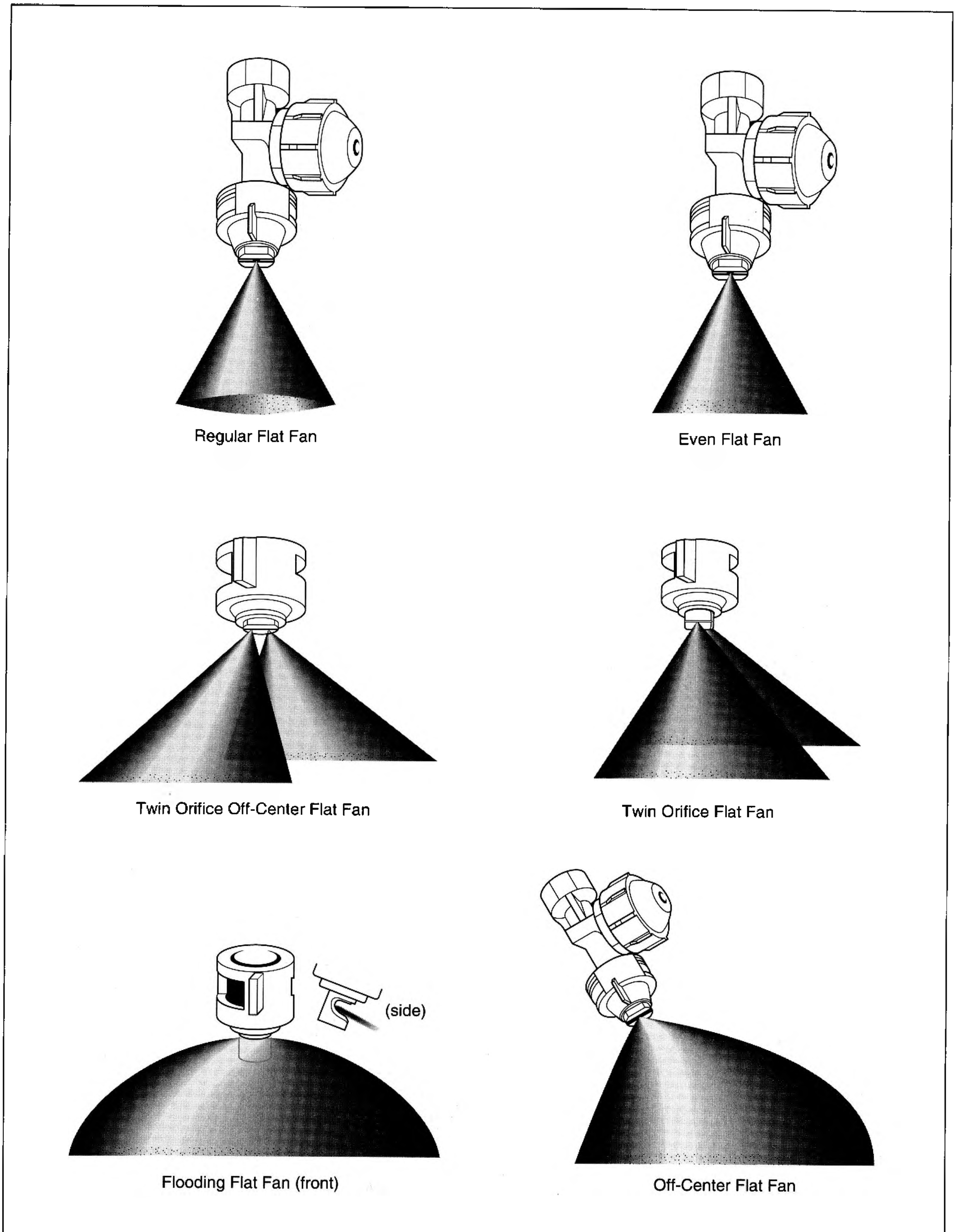


Figure 1. Spray nozzles that produce flat spray patterns.

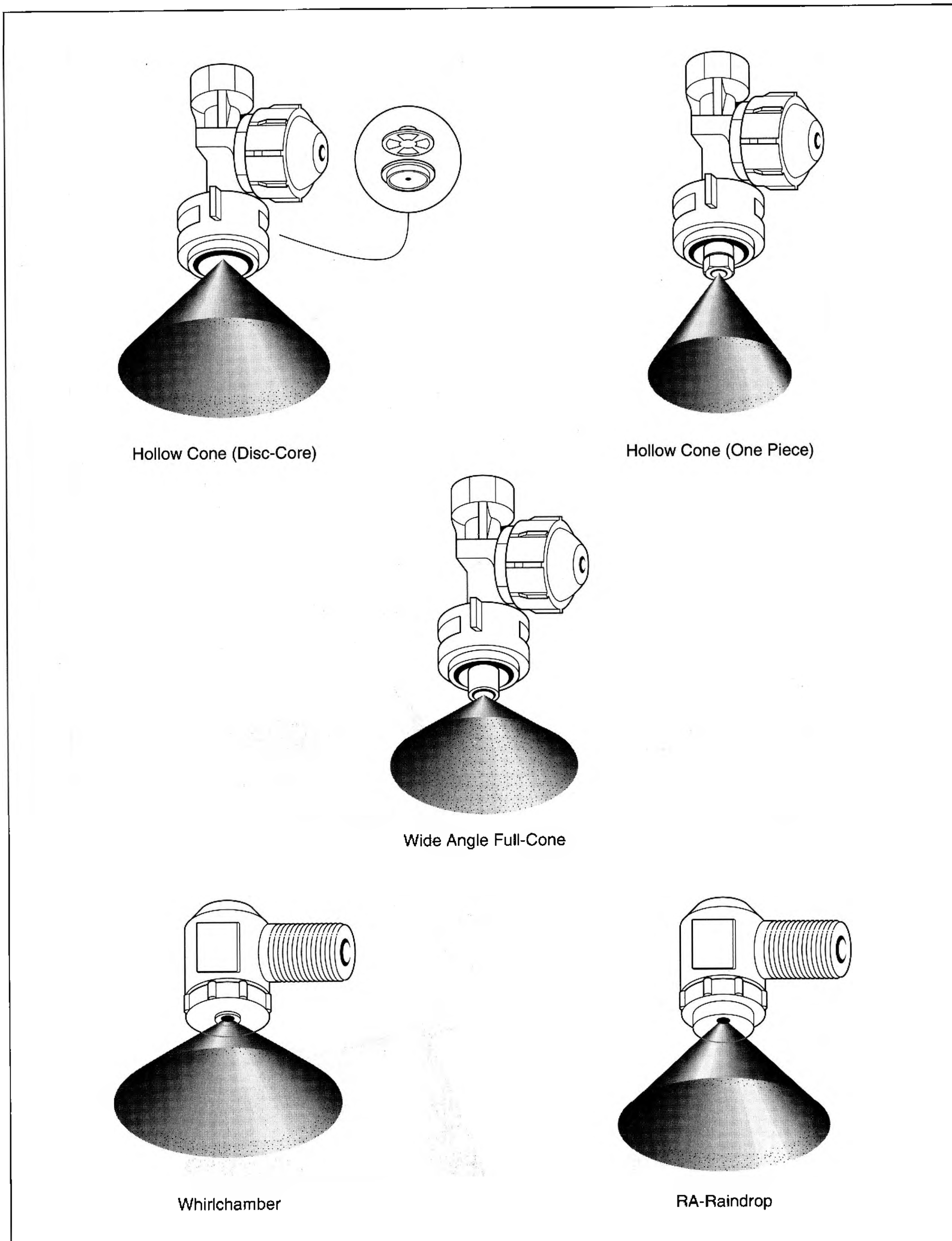


Figure 2. Spray nozzles that produce cone spray patterns.

Table 1. Recommended Nozzle Types for Various Applications (x denotes recommended use)

	Nozzle type									
Type of application	Flat-fan	Even flat-fan	Even twin	Regular twin	Flood	Hollow-cone	Whirl-chamber	Rain-drop	Wide-angle full-cone	Pre-orifice flat-fan
Preemergence herbicide										
Broadcast	x	-	-	-	x	-	-	x	x	x
Band	-	x	-	-	-	-	-	-	-	-
Postemergence herbicide										
Contact										
Band	-	x	x	-	-	x	-	-	-	-
Broadcast	x	-	-	x	-	-	x	-	-	-
Systemic										
Band	-	x	-	-	-	-	-	-	-	-
Broadcast	x	-	-	-	x	-	-	x	x	x
Insecticides										
Incorporation	x	-	-	-	x	-	-	x	x	x
Foliar banding	-	x	x	-	-	x	-	-	-	-
Broadcast	x	-	-	x	-	-	x	-	-	-
Soil incorporation	x	-	-	-	x	-	-	x	x	x

Table 2. Nomenclature for Various Types of Commercially Available Nozzles

Nozzle type	Nozzle nomenclature			
	Delavan	Spraying Systems	Lurark	Chem Farm
Flat-fan (regular, extended range, pre-orifice)	LF, LFR, R, RF	XR, DG	F	
Even-fan	LE	E	E	
Low-pressure flat-fan		LP		
Twin-orifice and twin-orifice even	2LF	TJ, TJE		
Off-center	LX	OC	OC	
Flooding	D or F	TK, K, TF	AN	
Whirlchamber, Raindrop, wide-angle full-cone	WRW, RA	FL, B, W	HW	MC
Hollow-cone	HB, HC	TX	AF	
Hollow-cone (disc and core type)	DC		DC	
Flooding, Raindrop, and whirlchamber (high-capacity)	F, WRW	K, QCK	AN	

Table 3. Color Code Comparisons for Commercially Available Spray Nozzles

Color	Nozzle number, size, and angle	
	Spraying Systems (VisiFlo)	Delavan (ColorJet)
Orange	8001, 11001 XR8001, XR11001 8001E TJ60-650134 TX-18 QCK-120	80-3, 110-3 RF-3 80-3R, 110-3R F150 80-3E, 40-3E
Dark green	80015, 110015 XR80015, XR110015 80015E QCK-180 TX-4 DG80015, DG110015	80-6, 110-6 RF-6 80-6R, 110-6R D-3 RA-6 WRW6 F30 RA60 WRW60 80-6E, 40-6E

Table 3. Color Code Comparisons for Commercially Available Spray Nozzles (cont.)

	Nozzle number, size, and angle	
Color	Spraying Systems (VisiFlo)	Delavan (ColorJet)
Yellow	8002, 11002 XR8002, XR11002 8002E TJ60-6502, TJ60-8002 TJ60-4002E, TJ60-8002E QCK-30 DG8002, DG11002	80-4, 110-4 RF-4 80-4R, 110-4R RA-4 D-2 WRW4 F20 RA-40 WRW 40 80-4E, 40-4E
Dark blue	8003, 11003 XR8003, XR11003 8003E TJ60-6503, TJ60-8003, TJ60-11003 TJ60-4003E, TJ60-8003E QCK-60 DG8003, DG11003	80-5, 110-5 RF-5 80-5R, 100-5R D2.5 RA-5 WRW5 80-5E, 40-5E
Red	8004, 11004 XR8004, XR11004 8004E TJ60-6504, TJ60-8004, TJ60-11004 TJ60-4004E, TJ60-8004E TK-2, TF-2 TX-6 QCK-40 DG8004, DG11004	80-8, 110-8 RF-8 80-8R, 110-8R D4 RA-8 F-40 RA-80 WRW-80 80-8E, 40-8E
Brown	8005, 11005 XR8005, XR11005 8005E FL-5 TK-2.5, TF-2.5 TX-12 QCK-150 DG8005, DG11005	80-1.5, 110-1.5 RF-1.5 80-1.5R, 110-1.5R 80-1.5E, 40-1.5E
Gray	8006, 11006 XR8006, XR11006 8006E TJ60-6506, TJ60-8006, TJ60-11006 FL-6.5 TK-3, TF-3 TX-8 TJ60-8006E QCK-50	80-2, 100-2, 110-2 RF-2 80-2R, 110-2R RA-2 WRW2 80-2E, 40-2E

Table 3. Color Code Comparisons for Commercially Available Spray Nozzles (cont.)

Color	Spraying Systems (VisiFlo)	Delavan (ColorJet)
White	8008, 11008 XR8008, XR11008 8008E TJ60-6508, TJ60-8008, TJ60-11008 FL-8 TK-4, TF-4 QCK-20	
Light blue	TJ60-8010, TJ60-11010 FL-10 TK-5, TF-5 QCK-100	80-15, 110-15 D7.5 WRW15 80-15E RA 15
Light green	FL-15 TK-7.5, T-F 7.5	80-20 D-10 RA15 WRW20 F100 RA200 WRW200
Black	TK-10, TF-10 TX-10 QCK-80	RF-1 WRW1.5
Tan		80-10, 110-10 D-5 RA-10 WRW-10 F50 RA-100 WRW-100 80-10E
Purple	QCK-210	D-6 F-60 RA-120 WRW120
Medium blue		F-80 RA-160 WRW160
Gold		F-120 RA240 WRW240

Table 4. Spray Coverage Required to Obtain Proper Overlap of Spray Patterns

Overlap (%)	Spray coverage at various nozzle spacings 20"	25"	30"	35"	40"	50"	60"
20	24	30	36	42	48	60	72
30	26	33	39	46	52	65	78
40	28	35	42	49	56	70	84
50	30	38	45	53	60	75	90
60	32	40	48	56	64	80	96
70	34	43	51	60	68	85	102
80	36	45	54	63	72	90	108
90	38	48	57	67	76	95	114
100	40	50	60	70	80	100	120
110	42	53	63	74	84	105	126
150	50	63	75	88	100	125	150

Table 5. Computed Spray Coverage at Different Spray Heights for Various Spray Angles

Spray angle (degrees)	Width of spray pattern at various distances from nozzle orifice 6"	8"	12"	15"	18"	24"	30"	36"	42"	48"	60"
15	1.6	2.1	3.2	3.9	4.7	6.3	7.9	9.5	11.1	12.6	15.8
25	2.7	3.5	5.3	6.6	8.0	10.6	13.3	15.9	18.6	21.2	26.6
30	3.2	4.3	6.4	8.0	9.7	12.8	16.0	19.3	22.4	25.9	32.0
40	4.3	5.8	8.7	10.9	13.0	17.4	21.6	26.2	30.6	34.9	42.8
45	4.9	6.6	9.9	12.4	14.9	19.8	24.8	29.8	34.8	39.7	49.6
50	5.6	7.4	11.2	14.0	16.8	22.4	28.0	33.6	39.1	44.8	56.0
60	6.9	9.2	13.9	17.3	20.8	27.6	34.6	41.6	48.4	55.4	69.2
65	7.6	10.2	15.2	19.1	22.9	30.5	38.1	45.8	53.2	61.0	76.4
70	8.2	11.2	16.8	21.0	25.2	33.6	42.0	50.4	59.8	67.2	84.0
73	8.8	11.8	17.8	22.2	26.6	36.4	44.4	53.2	62.0	71.0	88.5
75	9.2	12.3	18.4	23.0	27.6	26.8	46.0	55.2	64.2	73.5	92.0
80	10.1	13.4	20.1	25.2	30.2	40.2	50.2	60.4	72.5	80.8	100.0
90	12.0	16.0	24.0	30.0	36.0	48.0	60.0	72.0	84.0	96.0	120.0
100	14.3	19.1	28.6	35.8	42.4	57.2	71.4	86.0	100.0	114.6	143.0
120	20.8	27.8	41.6	52.0	62.4	83.0	104.0	125.0	145.8	166.2	208.0
140	33.0	44.0	65.9	82.4	98.9	131.9	164.8	197.8	230.8	263.8	329.7

Table 6. Summary of Recommended Procedures for Reducing Drift Damage

Recommended procedure	Example	Explanation
Select nozzle type that produces coarse droplets.	Raindrop, wide-angle full-cone, flooding	Use droplets as large as practical to provide necessary coverage.
Use lower end of pressure range.	Use 20 to 40 psi for Raindrop. Less than 25 psi for other types.	Higher pressures generate many more small droplets (less than 100 microns).
Lower boom height.	Use as low a boom height as possible to maintain uniform distribution. Use drops for systemic herbicides in corn.	Wind speed increases with height. Boom height a few inches lower can reduce off-target drift.
Increase nozzle size.	If normal gallonage is 15 to 20 gpa, increase to 25 to 30 gpa.	Larger capacity nozzles will reduce spray depositing off-target.
Spray when wind speeds are less than 10 mph and moving away from sensitive plants.	Leave a buffer zone if sensitive plants are downwind. Spray buffer zone when wind changes.	More of the spray volume will move off-target as wind increases.
Do not spray when the air is completely calm or an inversion exists.	Inversions generally occur in early morning or near bodies of water.	Calm air or inversions reduce air mixing, and spray can move slowly downwind.
Use a drift control additive when needed.	Several long-chain polymers are available (see Table 7).	Drift control additives increase the average droplet size produced by the nozzles.

Table 7. Drift Control Agents, Percent Principal Agents, Suggested Rates, and Sources[a]

Product	Principal agent	Rate/100 gal[b]	Company
More	polyvinyl polymer (30% polyacrylamide)	4 to 10 oz	Exacto Chemical Co. P.O. Box 90 Solon Mills, IL 60080 (815) 675-6060 (800) 798-9761
Formula 358	polyvinyl polymer (1% polyacrylamide)	1 to 4 qt	
Chem-Trol	polyvinyl polymer (1% polyacrylamide)	1 to 4 qt	Loveland Industries, Inc. P.O. Box 1289 Greeley, CO 80632 (303) 356-8920
38-F	30% polyacrylamide polymer	2 to 5 oz	
Direct	polyvinyl polymer (30% polyacrylamide)	1 to 2 oz	Precision Laboratories P.O. Box 127 Northbrook, IL 60065 (800) 323-6280
Windbrake	30% polyacrylamide polymer	5 oz	Terra International, Inc. 3506 N. Mattis Ave. Champaign, IL 61821 (217) 398-1575
Polycontrol-2	30% polyacrylamide copolymer	3 to 8 oz	JBL International Chemical, Inc. P.O. Box 6006 Vero Beach, FL 32960 (407) 562-0555
Driftgard	25% anionic polyacrylamide	4 to 8 oz	Custom Chemicides P.O. Box 11216 Fresno, CA 93772 (209) 264-0441
Drifgon	30% polyvinyl polymer 20% polysaccharide polymer	2 to 10 oz	SanAg 3959 Goodwin Ave. Los Angeles, CA 90039 (213) 245-6781
41-A DF	27% polyacrylamide polymer 3% polysaccharide polymer	3 to 4 oz	
38F	32% polyacrylamide polymer	4 to 8 oz	

Table 7. Drift Control Agents, Percent Principal Agents, Suggested Rates, and Sources (cont.)[a]

Product	Principal agent	Rate/100 gal[b]	Company
Spray-Trol	polyoxyethelene	1 to 3 oz	Spectrum Technologies, Inc. Plainfield, IL 60544 (815) 436-4440
Storm 1	1% polyacrylamide	1 to 3 qt	Tomorrow's Technologies, Inc. P.O. Box 27 Burlington, WI 53105 (414) 767-0555
Storm 32	30% polyamide copolymer	2 to 4 oz	
Storm 32CR	dry crystal	1 to 3 oz	
Storm 32SP	soluble packets	1 to 2 packets	
Nalcotrol	30% polyvinyl polymer	4 to 8 oz	Nalco Chemical Co. 1 Nalco Center Naperville, IL 60563-1198 (708) 305-1000
Nalcotrol II	30% polyamide copolymer	4 to 8 oz	
Stayput	1% polyvinyl polymer	1 to 3 qt	

[a]Trade names are for specific information only and do not constitute a guarantee or warranty of the product by the University of Illinois or imply endorsement of the product over other products not mentioned. Precautions should be taken to refer to drift reduction agent labels for specific application recommendations.
[b]Aerial, ground, and air-carrier application rates will vary.

Table 8. Pressure Drop for Water Flow Through Various Hose Sizes (in Good, Smooth Condition)

	Pressure drop in pounds per square inch (10-foot length—without couplings)								
Flow in GPM	1/4" I.D.*	3/8" I.D.	7/16" I.D.	1/2" I.D.	5/8" I.D.	3/4" I.D.	1" I.D.	1-1/4" I.D.	1-1/2" I.D.
0.2	0.3								
0.3	0.6								
0.4	1.0								
0.5	1.4	0.2							
0.5	2.0	0.3							
0.8	3.3	0.5							
1.0		0.7	0.3						
1.5		1.4	0.6	0.4					
2.0		2.4	1.1	0.6					
2.5		3.4	1.7	0.9					
3.0			2.4	1.2	0.4				
4.0				2.0	0.7				
5.0				2.9	1.0	0.4			
6.0				4.0	1.4	0.6			
8.0					2.6	0.9	0.3		
10					3.6	1.4	0.4		
15						3.0	0.8	0.3	
20							1.4	0.5	0.2
25							2.0	0.7	0.3
30							2.8	0.9	0.4
40								1.6	0.5
50								2.5	0.8
60								3.4	1.2
70									1.6
80									2.0
90									2.6
100									3.0

*Inside diameter.

Table 9. Flow of Water Through Schedule 40 Steel Pipe (Seamless or Welded Construction in Good, Clean Condition)

Numbers underlined are recommended values for recommended maximum capacity to keep velocity at approximately 5 feet per second.

Flow in GPM	Pressure drop in PSI for various pipe sizes (in 10-foot length) 1/8"	1/4"	3/8"	1/2"	3/4"	1"	1-1/4"	1-1/2"	2"
0.3	0.42								
0.4	0.70	0.16							
0.5	1.1	0.24							
0.6	1.5	0.33							
0.8	2.5	0.54	0.13						
1.0	3.7	0.83	0.19	0.06					
1.5	8.0	1.8	0.40	0.12					
2.0	13.4	3.0	0.66	0.21	0.05				
2.5		4.5	1.0	0.32	0.08				
3.0		6.4	1.4	0.43	0.11				
4.0		11.1	2.4	0.74	0.18	0.06			
5.0			3.7	1.1	0.28	0.08			
6.0			5.2	1.6	0.38	0.12			
8.0			9.1	2.8	0.66	0.20	0.05		
10				4.2	1.0	0.30	0.08		
15					2.2	0.64	0.16	0.08	
20					3.8	1.1	0.28	0.13	
25						1.7	0.42	0.19	0.06
30						2.4	0.59	0.27	0.08
35								0.36	0.11
40								0.47	0.14
45									0.17
50									0.20
60									0.29
70									0.38
80									0.50
90									0.62
100									0.76

Table 10. Approximate Friction Loss in Pipe Fittings in Terms of Equivalent Feet of Straight Pipe

Pipe size, standard weight	Actual inside diameter, inches	Gate value FULL OPEN	Globe value FULL OPEN	45 elbow	Run or standard tee	Standard elbow or run of tee reduced 1/2	Standard tee through side outlet
1/8	0.269	0.1	8	0.3	0.4	0.7	1.4
1/4	0.364	0.2	11	0.5	0.6	1.1	2.2
1/2	0.622	0.3	18	0.7	1.1	1.7	3.3
3/4	0.824	0.4	23	0.9	1.4	2.1	4.2
1	1.049	0.5	29	1.2	1.8	2.6	5.3
1-1/4	1.380	0.7	38	1.6	2.3	3.5	7.0
1-1/2	1.610	0.8	45	1.9	2.7	4.1	8.1
2	2.067	1.1	58	2.4	3.5	5.2	10.4
2-1/2	2.469	1.3	69	2.9	4.2	6.2	12.4
3	3.068	1.6	86	3.6	5.2	7.7	15.5
4	4.026	2.1	113	4.7	6.8	10.2	20.3
5	5.047	2.7	142	5.9	8.5	12.7	25.4
6	6.065	3.2	170	7.1	10.2	15.3	31.0

Table 11. Flow Rate of Flat-Fan Nozzles at Various Pressures

In the following tables, please note regarding manufacturer tip numbers: Some nozzles may not interchange exactly among manufacturers. However, tolerances are such that in most cases flow rates are practically identical.

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Spraying Systems XR8001 (XR11001)	15	0.06	7.7
Lurmark 01-F80	20	0.07	9.0
Hardi 2080-10 (4110-10)	30	0.09	11.5
Delavan RF-1	40	0.10	12.8
(100 mesh)	50	0.11	14.1
Spraying Systems XR80015 (XR110015) (DG80015) (DG110015)	15	0.09	11.5
Delavan (80-1.5R) (110-1.5R)	20	0.11	14.1
Lurmark 015-F80	30	0.13	16.6
Hardi 2080-12 (4110-12)	40	0.15	19.2
Delavan RF-1.5	50	0.17	21.8
(100 mesh)			
Spraying Systems XR8002 (XR11002) (DG8002) (DG11002)	15	0.12	15.4
Delavan (80-2R) (110-2R)	20	0.14	17.9
Lurmark 02-F80	30	0.17	21.8
Hardi 2080-14 (4110-14)	40	0.20	25.6
Delavan RF-2	50	0.23	29.4
(50 mesh)			
Spraying Systems XR8003 (XR11003) (DG8003) (DG11003)	15	0.18	23.0
Delavan (80-3R) (110-3R)	20	0.21	26.9
Lurmark 03-F80	30	0.26	33.3
Hardi 2080-16 (4110-16)	40	0.30	38.4
Delavan RF-3	50	0.34	43.5
(50 mesh)			
Spraying Systems XR8004 (XR11004) (DG8004) (DG11004)	15	0.24	30.7
Delavan (80-4R) (110-4R)	20	0.28	35.8
Lurmark 04-F80	30	0.35	44.8
Hardi 2080-20 (4110-20)	40	0.40	51.2
Delavan RF-4	50	0.45	57.6
(50 mesh)			

Table 11. Flow Rate of Flat-Fan Nozzles at Various Pressures (cont.)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Spraying Systems XR8005 (XR11005) (DG8005) (DG11005) Delavan (80-5R) (110-5R) Lurmark 05-F80 Delavan RF-5 (50 mesh)	15	0.31	39.7
	20	0.35	44.8
	30	0.43	55.0
	40	0.50	64.0
	50	0.56	71.7
Spraying Systems XR8006 (XR11006) Delavan (80-6R) (110-6R) Lurmark 06-F80 Hardi 2080-24 (4110-24) Delavan RF-6 (50 mesh)	15	0.37	47.4
	20	0.42	53.7
	30	0.52	66.6
	40	0.60	76.8
	50	0.67	85.8
Spraying Systems XR8008 (XR11008) Delavan (80-8R) (110-8R) Lurmark 08-F80 Hardi 2080-30 (4110-30) Delavan RF-8 (50 mesh)	15	0.49	62.7
	20	0.57	73.0
	30	0.69	88.3
	40	0.80	102.0
	50	0.89	114.0
Spraying Systems XR8010 (XR11010) Delavan 80-10 Lurmark 10-F80 Hardi 2080-36 (4110-36)	15	0.61	78.1
	20	0.71	90.9
	30	0.87	111.4
	40	1.00	128.0
	50	1.12	143.4
Spraying Systems XR8015 (XR11015) Delavan 80-15 Lurmark 15-F80	15	0.92	117.8
	20	1.06	136.0
	30	1.30	166.0
	40	1.50	192.0
	50	1.68	215.0
Spraying Systems 8020 Delavan 80-20 Lurmark 20-F80 Hardi 2080-50	15	1.20	153.6
	20	1.41	180.0
	30	1.73	221.0
	40	2.00	256.0
	50	2.23	285.4

Table 12. Flow Rate of Even-Fan Nozzles at Various Pressures

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity	
		gal/min (GPM)	oz/min (OPM)
Delavan 80-1E Spraying Systems 8001E Lurmark E9501 (100 mesh)	20 25 30 40	0.07 0.08 0.09 0.10	9.0 10.2 11.5 12.8
Delavan 80-1.5E Spraying Systems 80015E Lurmark E95015 (100 mesh)	20 25 30 40	0.11 0.12 0.13 0.15	14.1 15.4 16.6 19.2
Delavan 80-2E Spraying Systems 8002E Lurmark E9502 Hardi 4680-13E (50 mesh)	20 25 30 40	0.14 0.16 0.17 0.20	17.9 20.5 21.8 25.6
Delavan 80-3E Spraying Systems 8003E Lurmark E9503 Hardi 4680-15E (50 mesh)	20 25 30 40	0.21 0.24 0.26 0.30	26.9 30.7 33.3 38.4
Delavan 80-4E Spraying Systems 8004E Lurmark E9504 Hardi 4680-21E (50 mesh)	20 25 30 40	0.28 0.32 0.35 0.40	35.8 41.0 44.8 51.2
Delavan 80-5E Spraying Systems 8005E Lurmark E9505 Hardi 4680-25E (50 mesh)	20 25 30 40	0.35 0.40 0.43 0.50	44.8 51.2 55.0 64.0
Delavan 80-6E Spraying Systems 8006E Lurmark E9506 Hardi 4680-27E (50 mesh)	20 25 30 40	0.42 0.47 0.52 0.60	53.7 60.2 66.6 76.8

Table 12. Flow Rate of Even-Fan Nozzles at Various Pressures (cont.)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Delavan 80-8E Spraying Systems 8008E Lurmark E9508 Hardi 4680-33E (50 mesh)	20	0.57	73.0
	25	0.63	80.6
	30	0.69	88.3
	40	0.80	102.0
Delavan 80-10E Spraying Systems 8010E Lurmark E9510 Hardi 4680-37E	20	0.71	91.0
	25	0.79	101.0
	30	0.87	111.0
	40	1.00	128.0
Delavan 80-15E Spraying Systems 8015E Lurmark E9515	20	1.06	136.0
	25	1.19	152.0
	30	1.30	166.0
	40	1.50	192.0

Table 13. Twin-Orifice Fan Nozzles and Twin-Orifice Even Nozzles

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity	
		gal/min (GPM)	oz/min (OPM)
Spraying Systems 150-02 Delavan 2LF-2 Spraying Systems TJ60-8002 and TJ60-8002E (100 mesh)	20 30 40 50 60	0.14 0.17 0.20 0.22 0.25	17.9 21.8 25.6 28.2 32.0
Spraying Systems 150-03 Delavan 2LF-3 Spraying Systems TJ60-8003 and TJ60-8003E (100 mesh)	20 30 40 50 60	0.21 0.26 0.30 0.34 0.37	26.9 33.3 38.4 43.5 47.4
Spraying Systems 150-04 Delavan 2LF-4 Spraying Systems TJ60-8004 and TJ60-8004E (50 mesh)	20 30 40 50 60	0.28 0.35 0.40 0.45 0.49	35.8 44.8 51.2 57.6 62.7
Spraying Systems 150-05 Delavan 2LF-5 (50 mesh)	20 30 40 50 60	0.35 0.43 0.50 0.56 0.61	44.8 55.0 64.0 71.7 78.1
Spraying Systems 150-06 Delavan 2LF-6 Spraying Systems TJ60-8006 and TJ60-8006E (50 mesh)	20 30 40 50 60	0.42 0.52 0.60 0.67 0.74	53.7 66.6 76.8 85.8 94.7
Spraying Systems 150-08 Delavan 2LF-8 Spraying Systems TJ60-8008 (50 mesh)	20 30 40 50 60	0.57 0.69 0.80 0.89 0.98	73.0 88.3 102.0 114.0 125.0
Spraying Systems 150-09 Delavan 2LF-9 (50 mesh)	20 30 40 50 60	0.64 0.78 0.90 1.00 1.10	81.9 99.8 115.0 128.0 141.0

Table 13. Twin-Orifice Fan Nozzles and Twin-Orifice Even Nozzles (cont.)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Spraying Systems 150-01 (200 mesh)	20	0.07	9.0
	30	0.09	11.5
	40	0.10	12.8
	50	0.11	14.1
	60	0.12	15.4
Spraying Systems 150-015 Delavan 2LF 1.5 (100 mesh)	20	0.11	14.1
	30	0.13	16.6
	40	0.15	19.2
	50	0.17	21.8
	60	0.18	23.0

Table 14. Off-Center Fan Nozzles

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Delavan LX-2 Spraying Systems OC-02 Lurmark OC2 (50 mesh)	20	0.14	17.9
	30	0.17	21.8
	40	0.20	25.6
	60	0.24	30.7
Delavan LX-3 Spraying Systems OC-03 Lurmark OC3 Hardi G150 (50 mesh)	20	0.21	26.9
	30	0.26	33.3
	40	0.30	38.4
	60	0.37	47.4
Delavan LX-4 Spraying Systems OC-04 Lurmark OC4 Hardi G200 (50 mesh)	20	0.28	35.8
	30	0.35	44.8
	40	0.40	51.2
	60	0.49	62.7
Delavan LX-6 Spraying Systems OC-06 Lurmark OC6 (50 mesh)	20	0.42	53.8
	30	0.52	66.6
	40	0.60	76.8
	60	0.73	93.4

Table 14. Off-Center Fan Nozzles (cont.)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Delavan LX-8	20	0.57	73.0
Spraying Systems OC-08	30	0.69	88.3
Lurmark OC8	40	0.80	102.4
Hardi G250	60	0.98	125.4
(50 mesh)			
Delavan LX-12	20	0.85	108.8
Spraying Systems OC-12	30	1.00	128.0
Lurmark OC12	40	1.20	153.6
	60	1.50	192.0
Delavan LX-16	20	1.11	142.1
Spraying Systems OC-16	30	1.41	180.5
Lurmark OC16	40	1.60	204.8
	60	2.00	256.0

Table 15. Flooding Nozzles

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Spraying Systems TK-.5	10	0.05	6.4
Lurmark AN0.5	20	0.07	9.0
(100 mesh)	30	0.08	10.2
	40	0.10	12.8
Delavan D.75 (F.75)	10	0.075	9.6
Spraying Systems TK-.75	20	0.11	14.1
Lurmark AN0.75	30	0.13	16.7
(100 mesh)	40	0.15	19.2
Delavan D1 (F1)	10	0.10	12.8
Spraying Systems TK-1	20	0.14	17.9
Lurmark AN1	30	0.17	21.8
(100 mesh)	40	0.20	25.6

Table 15. Flooding Nozzles (cont.)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Delavan D1.5 (F1.5)	10	0.15	19.2
Spraying Systems TK-1.5	20	0.21	26.9
Lurmark AN1.5	30	0.26	33.3
Hardi 4598-10	40	0.30	38.4
(50 mesh)			
Delavan D2 (F2)	10	0.20	25.6
Spraying Systems TK-2 (TF-2)	20	0.28	35.8
Lurmark AN2	30	0.35	44.8
Hardi 4598-12	40	0.40	51.2
(50 mesh)			
Delavan D2.5 (F2.5)	10	0.25	32.0
Spraying Systems TK-2.5 (TF-2.5)	20	0.35	44.8
Lurmark AN2.5	30	0.43	55.0
Hardi 4598-14	40	0.50	64.0
(50 mesh)			
Delavan D3 (F3)	10	0.30	38.4
Spraying Systems TK-3 (TF-3)	20	0.42	53.8
Lurmark AN3	30	0.52	66.6
(50 mesh)	40	0.60	76.8
Delavan D4 (F4)	10	0.40	51.2
Spraying Systems TK-4 (TF-4)	20	0.57	73.0
Lurmark AN4	30	0.69	88.3
Hardi 4598-16	40	0.80	102.4
Delavan D5 (F5)	10	0.50	64.0
Spraying Systems TK-5 (TF-5)	20	0.71	90.9
Lurmark AN5	30	0.87	111.4
Hardi 4598-18	40	1.00	128.0
Delavan D6	10	0.60	76.8
Hardi 4598-20	20	0.85	108.8
	30	1.0	128.0
	40	1.2	153.6
Delavan D7.5 (F7.5)	10	0.75	96.0
Spraying Systems TK-7.5 (TF-7.5)	20	1.11	142.1
Lurmark AN7.5	30	1.31	167.7
	40	1.5	192.0

Table 15. Flooding Nozzles (cont.)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity	
		gal/min (GPM)	oz/min (OPM)
Delavan D10 (F10)	10	1.0	128.0
Spraying Systems TK-10 (TF-10)	20	1.4	179.2
Lurmark AN10	30	1.7	217.6
	40	2.0	256.0
Delavan D15 (F15)	10	1.5	192.0
Spraying Systems TK-15	20	2.1	268.8
	30	2.6	332.8
	40	3.0	384.0
Delavan D20 (F20)	10	2.0	256.0
Spraying Systems TK-20	20	2.8	358.4
Lurmark AN20	30	3.5	448.0
	40	4.0	512.0
Spraying Systems TK-30	10	3.0	384.0
Delavan (F30)	20	4.2	537.6
	30	5.2	565.6
	40	6.0	768.0

Table 16. Whirlchamber, Raindrop, and Wide-Angle Full-Cone Nozzles

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity	
		gal/min (GPM)	oz/min (OPM)
Delavan 1/4WRW2	10	0.10	12.8
Delavan RA-2	20	0.14	17.9
Lurmark HW2	30	0.17	21.8
(50 mesh)	40	0.20	25.6
	50	0.22	28.2
	60	0.24	30.7
Chem Farm MC1.25	10	0.13	16.6
(50 mesh)	20	0.18	23.0
	30	0.22	28.2
	40	0.25	32.0
	50	0.28	35.8
	60	0.31	39.7

Table 16. Whirlchamber, Raindrop, and Wide-Angle Full-Cone Nozzles (cont.)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity	
		gal/min (GPM)	oz/min (OPM)
Delavan 1/4WRW4 Delavan RA-4 Lurmark HW4 (50 mesh)	10	0.20	25.6
	20	0.28	35.8
	30	0.35	44.8
	40	0.40	51.2
	50	0.45	57.6
	60	0.49	62.7
Delavan 1/4WRW5 Delavan RA-5 Spraying Systems FL-5 Chem Farm MC2.5 (50 mesh)	10	0.25	32.0
	20	0.35	44.8
	30	0.43	55.0
	40	0.50	64.0
	50	0.56	71.7
	60	0.61	78.1
Delavan 1/4WRW6 Delavan RA-6 Lurmark HW6 (50 mesh)	10	0.30	38.4
	20	0.42	53.8
	30	0.52	66.6
	40	0.60	76.8
	50	0.67	85.8
	60	0.73	93.4
Delavan RA8 Spraying Systems FL-8	10	0.40	51.2
	20	0.57	73.0
	30	0.70	89.6
	40	0.80	102.4
	50	0.90	115.2
	60	0.99	126.7
Delavan 1/4WRW10 Spraying Systems 1/4B-SS5-5W Delavan RA-10 Spraying Systems FL-10 Lurmark HW10	10	0.50	64.0
	20	0.71	90.8
	30	0.87	111.4
	40	1.00	128.0
	50	1.10	140.8
	60	1.20	153.6
Delavan 1/4WRW15 Delavan RA-15 Spraying Systems FL-15 Lurmark HW15	10	0.75	96.0
	20	1.10	140.8
	30	1.30	166.4
	40	1.50	192.0
	50	1.70	217.6
	60	1.80	230.4

Table 16. Whirlchamber, Raindrop, and Wide-Angle Full-Cone Nozzles (cont.)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Delavan 1/4WRW20	10	1.00	128.0
Spraying Systems 1/4B-SS10-10W	20	1.40	179.2
Lurmark HW20	30	1.70	217.6
	40	2.00	256.0
	50	2.20	281.6
	60	2.40	307.2

Table 17. Hollow-Cone Nozzles

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Delavan HB-1 (HC-1)	30	0.0145	1.8
Spraying Systems TX1	40	0.0167	2.1
Lurmark HAF0180	60	0.0200	2.6
(100 mesh)	75	0.0233	3.0
	90	0.0250	3.2
Delavan HB-2 (HC-2)	30	0.0283	3.6
Spraying Systems TX2	40	0.0333	4.3
Lurmark HAF0280	60	0.0400	5.1
(100 mesh)	75	0.0450	5.8
	90	0.0500	6.4
Delavan HB-3 (HC-3)	30	0.0433	5.5
Spraying Systems TX3	40	0.0500	6.4
Lurmark HAF0380	60	0.0617	7.9
(100 mesh)	75	0.0683	8.7
	90	0.0750	9.6
Delavan HB-4 (HC-4)	30	0.0583	7.5
Spraying Systems TX4	40	0.0667	8.5
Lurmark HAF0480	60	0.0817	10.5
(50 mesh)	75	0.0917	11.7
	90	0.1000	12.8
Delavan HB-6 (HC-6)	30	0.0867	11.1
Spraying Systems TX6	40	0.1000	12.8
Lurmark HAF0680	60	0.1217	15.6
(50 mesh)	75	0.1367	17.5
	90	0.1500	19.2

Table 17. Hollow-Cone Nozzles (cont.)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity	
		gal/min (GPM)	oz/min (OPM)
Delavan HB-8 (HC-8) Spraying Systems TX8 Lurmark HAF0880 (50 mesh)	30	0.1150	14.7
	40	0.1333	17.1
	60	0.1633	20.9
	75	0.1833	23.5
	90	0.2000	25.6
Delavan HB-10 (HC-10) Spraying Systems TX10 Lurmark HAF1080 (50 mesh)	30	0.1450	18.6
	40	0.1667	21.3
	60	0.2033	26.0
	75	0.2283	29.2
	90	0.2500	32.0
Delavan HB-12 (HC-12) Spraying Systems TX12 Lurmark HAF1280 (50 mesh)	30	0.1733	22.2
	40	0.2000	25.6
	60	0.2450	31.4
	75	0.2733	35.0
	90	0.3000	38.4
Delavan HB-18 (HC-18) Spraying Systems TX18 Lurmark HAF1880 (50 mesh)	30	0.2600	33.3
	40	0.3000	38.4
	60	0.3667	46.9
	75	0.4100	52.5
	90	0.4500	57.6
Delavan HB-26 (HC-26) Spraying Systems TX26 Lurmark HAF2680 (50 mesh)	30	0.3750	48.0
	40	0.4333	55.5
	60	0.5300	67.8
	75	0.5933	75.9
	90	0.6500	83.2

Table 18. Hollow-Cone Nozzles (Disc-Core Types)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity	
		gal/min (GPM)	oz/min (OPM)
Delavan DC2-13 Spraying Systems D2-13 Lurmark 2-13 Hardi 1553-10 Blue Swirl (50 mesh)	40	0.08	10.2
	60	0.10	12.8
	80	0.11	14.1
	100	0.12	15.4
	150	0.14	17.9

Table 18. Hollow-Cone Nozzles (Disc-Core Types) (cont.)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity	
		gal/min (GPM)	oz/min (OPM)
Delavan DC2-23 Spraying Systems D2-23 Lurmark 2-23 (50 mesh)	40 60 80 100 150	0.10 0.13 0.14 0.16 0.19	12.8 16.6 17.9 20.5 24.3
Delavan DC3-23 Spraying Systems D3-23 Lurmark 3-23 (25 mesh)	40 60 80 100 150	0.12 0.14 0.16 0.18 0.21	15.4 17.9 20.5 23.0 26.9
Delavan DC2-25 Spraying Systems D2-25 Lurmark 2-25 Hardi 1553-10 Black Swirl (25 mesh)	40 60 80 100 150	0.16 0.19 0.22 0.25 0.29	20.5 24.3 28.2 32.0 37.1
Delavan DC3-25 Spraying Systems D3-25 Lurmark 3-25 Hardi 1553-22 Blue Swirl (25 mesh)	40 60 80 100 150	0.19 0.23 0.26 0.29 0.35	24.3 29.4 33.3 37.1 44.8
Delavan DC3-45 Spraying Systems D3-45 Lurmark Hardi 1553-30 Blue Swirl (25 mesh)	40 60 80 100 150	0.23 0.28 0.33 0.36 0.44	29.4 35.8 42.2 46.1 56.3
Delavan DC4-25 Spraying Systems D4-25 Lurmark 4-25 Hardi 1553-40 Blue Swirl (25 mesh)	40 60 80 100 150	0.29 0.35 0.40 0.45 0.54	37.1 44.8 51.2 57.6 69.1
Delavan DC5-25 Spraying Systems D5-25 Lurmark 5-25 Hardi 1553-16 Gray Swirl (25 mesh)	40 60 80 100 150	0.35 0.42 0.48 0.54 0.65	44.8 53.8 61.4 69.1 83.2

Table 18. Hollow-Cone Nozzles (Disc-Core Types) (cont.)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity	
		gal/min (GPM)	oz/min (OPM)
Delavan DC4-45	40	0.36	46.1
Spraying System D4-45	60	0.43	55.0
Lurmark 4-45	80	0.50	64.0
Hardi 1553-18 Gray Swirl	100	0.56	71.7
(25 mesh)	150	0.68	89.0
Delavan DC5-45	40	0.45	57.6
Spraying System D5-45	60	0.55	70.4
Lurmark 5-45	80	0.64	81.9
Hardi 1553-20 Gray Swirl	100	0.71	90.9
(25 mesh)	150	0.86	110.1
Delavan DC7-25	40	0.52	66.6
Spraying System D7-25	60	0.63	80.6
Lurmark 7-25	80	0.73	93.4
Hardi 1553-24 Gray Swirl	100	0.81	103.7
(16 mesh)	150	0.98	125.4
Delavan DC6-45	40	0.58	74.24
Spraying System D6-45	60	0.72	92.2
Lurmark 6-45	80	0.83	106.2
Hardi 1553-22 Black Swirl	100	0.93	119.0
(16 mesh)	150	1.15	147.2
Delavan DC7-45	40	0.68	87.0
Spraying System D7-45	60	0.84	107.5
Lurmark 7-45	80	0.97	124.2
Hardi 1553-24 Black Swirl	100	1.11	142.1
(16 mesh)	150	1.35	172.8
Delavan DC8-45	40	0.84	107.5
Lurmark 8-45	60	1.04	133.1
Hardi 1553-30 Black Swirl	80	1.21	154.9
(16 mesh)	100	1.35	172.8
	150	1.68	215.0
Delavan DC12-25	40	0.93	119.0
Spraying System D12-25	60	1.15	147.2
Lurmark 12-25	80	1.32	169.0
(16 mesh)	100	1.47	188.2
	150	1.81	231.7

Table 18. Hollow-Cone Nozzles (Disc-Core Types) (cont.)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity gal/min (GPM)	Capacity oz/min (OPM)
Delavan DC12-45	40	1.36	174.1
Spraying Systems D12-45	60	1.68	215.0
Lurmark 12-45	80	1.95	249.6
(16 mesh)	100	2.20	281.6
	150	2.69	344.3
Delavan DC8-46	40	1.84	235.5
Spraying Systems D8-46	60	2.25	288.0
(16 mesh)	80	2.62	335.4
	100	2.93	375.0
	150	3.60	460.8
Delavan DC10-46	40	2.48	317.4
Spraying System D10-46	60	3.05	390.4
(16 mesh)	80	3.53	451.8
	100	3.96	506.9
	150	4.83	618.2

Table 19. Flooding, Raindrop, and Whirlchamber Nozzles (High-Capacity)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity (gal/min, or GPM)
Delavan F20	10	2.0
Spraying Systems 1/8K-20	20	2.8
Delavan RA-40	30	3.5
Spraying Systems QCK-SS20	40	4.0
Delavan 3/4 WRW40	50	4.5
Lurmark AN20		
Delavan F30	10	3.0
Spraying Systems 3/8K-30	20	4.2
Delavan RA-60	30	5.2
Spraying Systems QCK-SS30	40	6.0
Delavan 3/4 WRW60	50	6.7
Lurmark AN30		

Table 19. Flooding, Raindrop, and Whirlchamber Nozzles (High-Capacity) (cont.)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity (gal/min, or GPM)
Delavan F40	10	4.0
Spraying Systems 3/8K-40	20	5.7
Delavan RA-80	30	6.9
Spraying Systems QCK-SS40	40	8.0
Delavan 3/4 WRW80	50	9.0
Lurmark AN40		
Delavan F50	10	5.0
Spraying Systems 1/2K-50	20	7.1
Delavan RA-100	30	8.7
Spraying Systems QCK-SS60	40	10.0
Delavan 3/4 WRW100	50	10.5
Lurmark AN50		
Delavan F60	10	6.0
Spraying Systems 1/2K-60	20	8.5
Delavan RA-120	30	10.4
Spraying Systems QCK-SS60	40	12.0
Delavan 3/4 WRW120	50	13.4
Lurmark AN60		
Delavan F80	10	8.0
Spraying Systems 1/2K-80	20	11.3
Spraying Systems QCK-SS80	30	13.9
Delavan RA-160	40	16.0
Delavan 3/4 WRW160	50	17.9
Lurmark AN80		
Delavan F100	10	10.0
Spraying Systems 3/4K-100	20	14.1
Delavan RA200	30	17.3
Spraying Systems QCK-SS100	40	20.0
Delavan 3/4 WRW200	50	22.3
Lurmark AN100		
Delavan F120	10	12.0
Spraying Systems 3/4K-20	20	17.0
Delavan RA-240	30	20.8
Spraying Systems QCK-SS120	40	24.0
Delavan 3/4 WRW240	50	26.8
Lurmark AN120		

Table 19. Flooding, Raindrop, and Whirlchamber Nozzles (High-Capacity)

Manufacturer tip number (nozzle screen size)	Liquid pressure (PSI)	Capacity (gal/min, or GPM)
Delavan F150 Delavan RA-300 Spraying Systems QCK-SS150	10 20 30 40 50	15.0 21.2 26.0 30.0 33.5
Delavan F180 Spraying Systems QCK-SS180	10 20 30 40	18.0 25.5 31.2 36.0
Delavan F210 Spraying Systems 3/4K-210 Spraying Systems QCK-SS210 Lurmark AN210	10 20 30 40	21.0 29.7 36.4 42.0
Spraying Systems 1K-300	10 20 30 40	30.0 42.4 52.0 60.0
Spraying Systems 1K-450	10 20 30 40	45.0 63.6 77.9 90.0

17 Insecticide Formulations and Toxicities

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This chapter is an abridged reference for trade names, common names, manufacturers, formulations, ecological hazards, toxicities, and signal words of several agricultural insecticides. We have included insecticides that are recommended for use in Illinois, some insecticides that are registered but are not recommended or used in Illinois, and some insecticides that are still experimental compounds.

This is *not* a list of recommended insecticides, nor is it to be used for determining what insecticide to use to control a particular insect. This reference compares common names of insecticides with trade names and catalogs their relative hazards and toxicities. Ultimate reliance should be placed on information supplied by pesticide manufacturers or on product labels. The use of trade names does not constitute an endorsement by the University of Illinois.

How to Use and Interpret This Reference

If you seek information about a particular insecticide, consult the alphabetically arranged trade names in Table 1 to identify the appropriate common name. Then consult the alphabetical listing of common names in Table 2 for more information on trade names, manufacturers or formulators, formulations, ecological hazards, toxicities, and signal words for each product.

When available, ratings of insecticide toxicity to fish, birds, and honey bees are provided. Those for bees can be interpreted readily as follows: (1) high: kills bees on contact and by residues; bees should be removed from area of application; (2) moderate: kills bees if applied over them; limited damage with correct dosage, timing, and method of application; (3) low: can be used around bees with few precautions and a minimum of injury.

The relative toxicities of insecticides to fish and birds must be interpreted from the available data. The primary test species for fish are rainbow trout and bluegills, but goldfish, golden orfe, carp, bass, catfish, guppies, harlequin fish, minnows, mosquito fish, and others have also been used by a number of different laboratories. The primary test species for birds are bobwhite quail, ringneck pheasants, and mallard ducks, but chickens, Japanese quail, canaries, ducks, pigeons, blackbirds, starlings, partridges, and others have also been used. As a consequence, the data for toxicity of various insecticides to fish and birds are relative ratings.

Oral and dermal toxicity values are expressed as LD_{50}, which indicates the size of the dose that is lethal to 50 percent of the test animals. The LD_{50} value is expressed as milligrams (mg) of actual insecticide per kilogram (kg) of body weight of the test animal —mg/kg.

Oral and dermal LD_{50} values reported in various sources sometimes differ markedly, depending on the carrier of the toxicant and the species, sex, age, and degree of fasting of the test animals. Acute oral toxicity values are usually obtained by feeding technical-grade products to white rats or rabbits; acute dermal toxicity is determined by skin absorption tests on rats or rabbits. However, white mice, guinea pigs, dogs, and other animals are sometimes used for these tests. Whenever possible, we used the data reported for white rats (acute oral toxicity) and rabbits (acute dermal toxicity). Because test results vary, an LD_{50} may be expressed as a range of values rather than a single value. With very few exceptions, the LD_{50} values are based on technical grade product, not on common formulations. Formulated products are usually less toxic than the technical material. Acute oral and dermal toxicities of formulated products are usually indicated on the products' Material Safety Data Sheets (MSDS).

By multiplying the LD_{50} value by 0.003, you can approximate the ounces of actual insecticide that would be lethal to one of every two 187-pound per-

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

sons. As an example, an oral LD_{50} value for malathion is 1,200 mg/kg; thus, if a group of people each weighing 187 pounds ate 3.6 ounces (1,200 x 0.003) of actual malathion per person, half of them would probably die. The dermal-toxicity-LD_{50} value of malathion is approximately 4,000 mg/kg, or, for a 187-pound person, 12 ounces. If you check the list of insecticides, you will find some highly toxic chemicals with LD_{50} values from 1 to 10 mg/kg. For the 187 lb-person, fatal doses of those chemicals would be in the range of 0.003 to 0.03 ounces.

The LD_{50} values are approximate, but they serve as a guide for comparing the toxicities of insecticides as well as indicating their comparative acute toxicity to other warm-blooded animals and humans. Acute toxicity values expressed as LD_{50} are classified according to their relative danger when being used. An acute oral LD_{50} of 500 mg/kg or higher is rated as low toxicity; an LD_{50} of 50 to 500 is rated as moderate toxicity; and an LD_{50} of less than 50 is rated as high toxicity.

References Consulted for This Chapter

To obtain information for this chapter, we consulted *Farm Chemicals Handbook '92*, published in 1992 by the Meister Publishing Company; the 8th Edition of the *Crop Protection Chemicals Reference*, published jointly in 1991 by John Wiley & Sons and the Chemical and Pharmaceutical Publishing Corporation; *Pesticide Fact Handbook*, U.S. Environmental Protection Agency, published in 1988 by Noyes Data Corporation; and *The Pesticide Manual: A World Compendium*, published in 1987 by the British Crop Protection Council. In addition, we consulted technical fact sheets provided by manufacturers.

Factual errors arising during the transcription of the information from these references are our responsibility. Please draw our attention to any errors or omissions so that we can make corrections to our next annual revision.

Table 1. Insecticide Trade Names

Trade name	Common name
Actellic	pirimiphos-methyl
Agree	*Bacillus thuringiensis* var. *kurstaki*
Agrox D-L Plus	combination of captan, diazinon, and lindane
Altosid	methoprene
Ambush	permethrin
Ammo	cypermethrin
Anthon	trichlorfon
Apollo	clofentezine
Asana	esfenvalerate
Atroban	permethrin
Aztec	combination of cyfluthrin and phostebupirim
Bactimos	*Bacillus thuringiensis* var. *israelensis*
Bactospeine	*Bacillus thuringiensis* var. *kurstaki*
Baygon	propoxur
Baytex	fenthion
Baythroid	cyfluthrin
Bidrin	dicrotophos
Biobit	*Bacillus thuringiensis* var. *kurstaki*
Black Leaf 40	nicotine
Bolstar	sulprofos
Broot	trimethacarb
Capture	bifenthrin
Carzol	formetanate
Chlor-O-Pic	chloropicrin
Co-Ral	coumaphos
Combot	trichlorfon
Comite	propargite
Compel	cucurbitacin plus a sticker
Condor	*Bacillus thuringiensis* var. *kurstaki*
Counter	terbufos
Cutter Blue	fenthion
Cutter Gold	cyfluthrin
Cygon	dimethoate
Cymbush	cypermethrin
Cythion	malathion
Danitol	fenpropathrin
DDVP	dichlorvos
De-Fend	dimethoate
Derris	rotenone
Detia	aluminum phosphide
Diacide	pyrethrin
Diacon	methoprene
Diazinon	diazinon
Dibrom	naled

Table 1. Insecticide Trade Names (cont.)

Trade name	Common name
Dimilin	diflubenzuron
Dipel	*Bacillus thuringiensis* var. *kurstaki*
Dipterex	trichlorfon
Disparlure	gyplure
Di-Syston	disulfoton
Dominator	pirimiphos-methyl
Dyfonate	fonofos
Dylox	trichlorfon
D·Z·N	diazinon
Ectiban	permethrin
Ectrin	fenvalerate
Equibot	trichlorfon
Eqvalon	ivermectin
Ethion	ethion
Expar	permethrin
Famphos	famphur
Foil	*Bacillus thuringiensis* var. *tenebrionis* and *kurstaki*
Force	tefluthrin
Fortress	chlorethoxyphos
Full-Bac	*Bacillus thuringiensis* var. *kurstaki*
Fumitoxin	aluminum phosphide
Furadan	carbofuran
Gammasan	lindane
Gastoxin	aluminum phosphide
Germate Plus	lindane + diazinon
Grasshopper Attack	*Nosema locustae*
Guthion	azinphos-methyl
Imidan	phosmet
Insectrin	permethrin
Ivomec	ivermectin
Javelin	*Bacillus thuringiensis* var. *kurstaki*
Karate	lambda-cyhalothrin
Kelthane	dicofol
Kicker	pyrethrin
Kryocide II	cryolite
Lannate	methomyl
Larvin	thiodicarb
Larvacide	chloropicrin
Larvadex	cyromazine
Lorsban	chlorpyrifos
Lysoff	fenthion
M-One	*Bacillus thuringiensis* var. *san diego*
Margosan-O	azadirachtin
Marlate	methoxychlor
Mavrik	fluvalinate
Mesurol	methiocarb
Metasystox-R	oxydemeton-methyl
Metho-gas	methyl bromide
Mitac	amitraz
Mocap	ethoprop
Monitor	methamidophos
Moorman's IGR	methoprene
Morestan	oxythioquinox
MVP	*Bacillus thuringiensis* var. *kurstaki*
Neem	azadirachtin
Neguvon	trichlorfon
Nemacur	fenamiphos
NOLO Bait	*Nosema locustae*
Off	DEET
Omite	propargite
Optimizer	diazinon
Orthene	acephate
Overtime	permethrin
Penncap-M	methyl parathion (encapsulated)
Permaban	permethrin
Permanone	permethrin
Permectrin	permethrin
Phosdrin	mevinphos
Phosphamidon	phosphamidon
Phostek	aluminum phosphide
Phostoxin	aluminum phosphide
Phthalthrin	tetramethrin
Pirimor	pirimicarb
Pounce	permethrin
Pyrenone	pyrethrins
Quasar	chloropicrin
Rabon	tetrachlorvinphos
Ravap	combination of dichlorvos and tetrachlorvinphos
Red Devil	sabadilla
Reldan	chlorpyrifos-methyl
Rotacide	rotenone
Rotator	pirimiphos-methyl
Ryania	ryania
Saber	lambda-cyhalothrin
Scout	tralomethrin
Sevimol	carbaryl
Sevin	carbaryl

Table 1. Insecticide Trade Names (cont.)

Trade name	Common name
Slam	combination of cucurbitacin and carbaryl
Spotton	fenthion
Spur	fluvalinate
Supracide	methidathion
Synerid	erythrosine-B
Synthrin	resmethrin
Taktic	amitraz
Tedion	tetradifon
Teknar	*Bacillus thuringiensis* var. *israelensis*
Temik	aldicarb
Tempo	cyfluthrin
Terminator	diazinon
Thimet	phorate
Thiodan	endosulfan
Thuricide	*Bacillus thuringiensis* var. *kurstaki*
Tiguvon	fenthion
Tomahawk	pirimiphos-methyl
Topside	*Bacillus thuringiensis* var. *kurstaki*
Trident II	*Bacillus thuringiensis* var. *tenebrionis*
Trigard	cyromazine
Vapona	dichlorvos
Vectobac	*Bacillus thuringiensis* var. *israelensis*
Vendex	fenbutatin-oxide
Vigilante	diflubenzuron
Vydate	oxamyl
Warbex	famphur
X-clude	pyrethrum
Xentari	*Bacillus thuringiensis* var. *kurstaki*

Table 2. Insecticide Formulations and Toxicities

Generic name (manufacturer)	Trade name	Formulations[a]	Toxicity to[b]			Acute LD_{50}[c]		Signal word
			Fish	Bee	Bird	Oral	Dermal	
acephate (Valent)	Orthene	SP	VL	H	M	700–980	>10,250	Caution
aldicarb (Rhone-Poulenc)	Temik	G	H	H	H	1	20	Danger
aluminum phosphide (Degesch Am., Pestcon, Research Products)	Detia, Fumitoxin, Gastoxin, Phostek, Phostoxin	tablets, pellets (fumigant)	—[d]	—[d]	—[d]	TLV[e]	0.3 ppm	Danger
amitraz (NOR-AM)	Mitac, Taktic	EC, WP	H	VL	L	800	>200	Warning
azadirachtin (W.R. Grace)	Margosan-O, Neem	WP	—	—	—	—	>10,000	Caution
azinphos-methyl (Miles)	Guthion	EL, F, ULV, WP	VH	H	M	10	200	Danger
Bacillus thuringiensis var. *israelensis* (Abbott Labs, PBI/ Gordon, Sandoz)	Bactimos, Teknar, Vectobac	F, G, SL, WP, pellets	NT	NT	NT	NT	NT	Caution
Bacillus thuringiensis var. *kurstaki* (Abbott Labs, DuPont, Hess & Clark, PBI/ Gordon, Ringer, Sandoz)	many	many	NT	NT	NT	NT	NT	Caution
Bacillus thuringiensis var. *san diego* (Mycogen, Inc.)	M-One	WP	NT	NT	NT	NT	NT	Caution
Bacillus thuringiensis var. *tenebrionis* (Sandoz)	Foil, Trident II	WP	NT	NT	NT	NT	NT	Caution
bifenthrin (FMC)	Capture	EC, WP	VH	H	VL	375	>2,000	Warning
carbaryl (Rhone-Poulenc)	Sevimol, Sevin	many	M	H	L	246–283	>2,000	Caution Warning
carbofuran (FMC, Miles)	Furadan	F, G	H	H	VH	11	10,200	Warning Danger
chlorethoxyphos (DuPont)	Fortress	G	H	—	H	1.8–4.8	12.5–18.5	Danger
chloropicrin (Great Lakes, Hopkins, Soweco)	Chlor-o-pic, Larvacide 100, Quasar	liquid fumigant	—[d]	—[d]	—[d]	TLV[e]	0.1 ppm	Danger
chlorpyrifos (DowElanco)	Lorsban	many	VH	H	H	96–270	2,000	Caution Warning

Table 2. Insecticide Formulations and Toxicities (cont.)

Generic name (manufacturer)	Trade name	Formulations[a]	Toxicity to[b]			Acute LD_{50}[c]		Signal word
			Fish	Bee	Bird	Oral	Dermal	
chlorpyrifos-methyl (DowElanco)	Reldan	EC	—[d]	—[d]	—[d]	1,000–3,700	>2,000	Danger
clofentezine (NOR-AM)	Apollo	SL, F	—	VL	—	>3,200	>2,400	Caution
coumaphos (Bayer AG)	Co-Ral	D, EC, F, pour-on	M	M	H	13–963	860–1,000+	Warning Danger
cryolite (Atochem)	Kryocide II	WP, D	L	NT	NT	13,500	—	Caution
cucurbitacin (Ecogen, MicroFlo)	Compel, Slam	SP (insect feeding stimulant)	—	—	—	340	—	Caution
cyfluthrin (Miles)	Baythroid, Cutter Gold, Tempo	many	VH	H	L	600	>5,000	Danger
cypermethrin (FMC, ICI)	Ammo, Cymbush	EC, ULV, WP	VH	H	L	250	>2,000	Caution Danger
cyromazine (CIBA-Geigy)	Larvadex, Trigard	feed premix, WP (insect growth regulator)	L	VL	VL	3,387	>3,100	Caution
DEET (McLaughlin-Gormley-King)	Off, others	in alcohol	—	—	—	2,000	10,000	Caution
diazinon (Atochem, CIBA-Giegy)	Diazinon, D-Z-N, Optimizer ear tags, Patriot ear tags, Terminator ear tags	many	VH	H	H	300–400	3,600	Caution Warning
dichlorvos (Fermenta, Loveland)	DDVP, Vapona, others	many	M	H	M	50	107	Danger
dicofol (Rohm and Haas)	Kelthane	EC, F, WP	H	VL	M	820–960	2,100	Caution Warning
dicrotophos (DuPont, CIBA-Geigy)	Bidrin	S	VL	H	—	17–22	224	Danger
diflubenzuron (Am. Cyanamid, Uniroyal)	Dimilin, Vigilante	G, WP, bolus, oil	VL	NT	VL	>4,640	>10,000	Caution
dimethoate (Am. Cyanamid)	Cygon, De-Fend	A, D, EC, ULV	H	H	H	255–310	>2,000	Warning
disulfoton (Miles)	Di-Syston	EC, G	M	M	H	2–10	6–20	Danger
endosulfan (FMC)	Thiodan	D, EC, G, ULV, WP	VH	M	M	23–160	359	Warning Danger

Table 2. Insecticide Formulations and Toxicities (cont.)

Generic name (manufacturer)	Trade name	Formulations[a]	Toxicity to[b]			Acute LD_{50}[c]		Signal word
			Fish	Bee	Bird	Oral	Dermal	
erythrosine-B (Hilton-Davis)	Synerid	bait	—	—	—	6,700–7,000	—	Caution
esfenvalerate (DuPont)	Asana	EC	VH	H	L	458	>2,000	Warning
ethion (FMC)	Ethion	D, EC, G, WP	H	H	L	21–191	838	Warning
ethoprop (Rhone-Poulenc)	Mocap	EC, G	H	M	VH	62	3	Warning Danger
eugenol (several)	—	attractant	—	—	—	500–5,000	—	—
famphur (Am. Cyanamid)	Famphos, Warbex	pour-on	—	H	H	48	2,730	Danger
fenamiphos (Miles)	Nemacur	EC, G	H	VL	H	3	200	Danger
fenbutatin-oxide (DuPont)	Vendex	L, WP	VH	H	L	2,631	>2,000	Danger
fenpropathrin (Valent)	Danitol	EC, F, ULV	M	H	L	71–164	2,000	Warning
fenthion (Miles)	Baytex, Cutter Blue, Lysoff, Spotton, Tiguvon	pour-on, spray concentrate, others	M	H	H	250	2,000	Warning
fenvalerate (DuPont)	Ectrin	D, G, WP, ear tags	VH	H	H	451	2,500	Warning
fluvalinate (Sandoz)	Mavrik, Spur	EC, F, ULV	VH	M	L	261–282	>20,000	Danger
fonofos (ICI)	Dyfonate	EC, G	H	H	H	8–18	25	Danger Warning
formetanate (NOR-AM)	Carzol	SP	M	M	H	20	>10,200	Danger
geraniol (several)	—	attractant	—	—	—	—	—	—
gyplure (National Chemical)	Disparlure	attractant	—	—	—	—	—	—
ivermectin (Merck)	Eqvalon, Ivomec	RTU injectable, RTU paste	M	H	M	650	2,000	Caution
lambda-cyhalothrin (ICI)	Karate, Saber	EC, ULV	VH	H	L	56–79	632	Danger
lindane (Rhone-Poulenc)	several	many	M	H	M	88–125	1,000	Warning

Table 2. Insecticide Formulations and Toxicities (cont.)

Generic name (manufacturer)	Trade name	Formulations[a]	Toxicity to[b]			Acute LD_{50}[c]		Signal word
			Fish	Bee	Bird	Oral	Dermal	
malathion (Am. Cyanamid Rhone-Poulenc)	Cythion, Malathion, others	many	H	H	M	1,000–2,800	4,100	Caution
metaldehyde (several)	several	bait	VL	VL	H	630	—	Caution Warning
methamidophos (Miles, Valent)	Monitor, others	L	M	H	H	20	118	Danger
methidathion (CIBA-Geigy)	Supracide	EC, WP, ULV	VH	H	M	44	200	Danger
methiocarb (Miles)	Mesurol	A, D, G, WP, bait	M	H	H	10–35	>5,000	Warning
methomyl (DuPont)	Lannate	L, SP	M	H	H	17–24	5,880	Danger
methoprene (Sandoz)	Altosid, Diacon, Moorman's IGR	EC, bait, briquets, (insect growth regulator)	M	L	VL	>34,600	>3,000	Caution
methoxychlor (Kincaid Enterprises)	Marlate, others	many	H	L	VL	6,000	2,820	Caution
methyl bromide (Great Lakes Chemical)	Metho-gas, others	liquid fumigant	—[d]	—[d]	—[d]	TLV[e]	5 ppm	Danger
methyl parathion (Bayer)	many	D, EC, ULV, WP	M	H	H	20–50	491	Danger
methyl parathion, encapsulated (Atochem)	Penncap-M	F	VL	H	H	>600	>5,400	Warning
mevinphos (Amvac Chemical)	Phosdrin	EC, SL	L	H	H	3–12	16–33	Danger
MGK-R326 (McLaughlin-Gormley-King)	—	repellent	—	—	—	5,230–7,230	—	Caution
naled (Valent)	Dibrom	D, EC, SL, oil	H	H	M	250	1,100	Danger
nicotine (Black Leaf Products)	Black Leaf 40, others	S	—	VL	L	50–60	50	Danger
Nosema locustae (Evans Biocontrol, Ringer)	Grasshopper Attack, NOLO Bait	WP, bait	NT	NT	NT	NT	VL	Caution
oxamyl (DuPont)	Vydate	SL	M	M	H	5	2,960	Danger

Table 2. Insecticide Formulations and Toxicities (cont.)

Generic name (manufacturer)	Trade name	Formulations[a]	Toxicity to[b] Fish	Bee	Bird	Acute LD_{50}[c] Oral	Dermal	Signal word
oxydemeton-methyl (Miles)	Metasystox-R	EC	H	H	H	30–75	150	Warning
oxythioquinox (Miles)	Morestan	D, F, WP	—	L	—	1,500	2,000	Caution
parathion (Bayer)	several	many	H	H	H	2–6	50	Danger
permethrin (FMC, ICI)	many	many	VH	H	VL	430–4,000	>2,000	Warning Danger
phorate (Am. Cyanamid)	Thimet	G	L	M	VH	2–4	4–9	Danger
phosmet (Gowan)	Imidan	WP	H	H	L	147–316	>4,640	Warning
phosphamidon (CIBA-Geigy)	Phosphamidon	L, SC, ULV	M	H	VH	17–30	267	Danger
phostebupirim (Miles)	Aztec (with cyfluthrin)	G	M	—	H	1.8–3.6	9.4–31	Danger
piperonyl butoxide (several)	many	synergist	NT	NT	—	>7,500	>7,950	Caution
pirimicarb (ICI)	Pirimor	many	VL	VL	H	147	>500	Warning
pirimiphos-methyl (ICI)	Actellic, Dominator, Rotator, Tomahawk	EC, ear tags, others	—[d]	—[d]	—[d]	>2,000	>4,592	Caution
propargite (Uniroyal)	Comite, Omite	EC, WP	H	VL	L	4,029	2,940	Danger
propoxur (Miles)	Baygon, others	D, EC, WP, bait	M	H	L	50–104	>500	Warning
pyrethrum, pyrethrins (several)	Diacide, Kicker, Pyrenone, X-clude, others	flower extract	H	L	VL	1,500	>1,800	Caution
resmethrin (Fairfield Am., Roussel)	many	many	VH	H	VL	>2,500	>3,000	Caution
rotenone (Fairfield Am., Prentiss, Roussel)	Derris, Rotacide, others	many	VH	VL	L	132–1500	1,000–3,000	Caution Danger
ryania (Agrisystems Inc.)	Ryania	—	H	—	—	1,200	—	Caution
sabadilla (several)	Red Devil	D	—	—	—	—	—	Caution
sulprofos (Miles)	Bolstar	EC	M	—	—	150	820	Warning

Table 2. Insecticide Formulations and Toxicities (cont.)

Generic name (manufacturer)	Trade name	Formulations[a]	Toxicity to[b] Fish	Bee	Bird	Acute LD_{50}[c] Oral	Dermal	Signal word
tefluthrin (ICI)	Force	G	VH	H	L	1,531–3,091	148–1,480	Warning
terbufos (Am. Cyanamid)	Counter	G	VH	M	H	4.5–9	1	Danger
tetrachlorvinphos (Fermenta)	Rabon, Ravap	EC, WP	H	H	VL	4,000–5,000	>2,500	Caution
tetradifon (Duphar)	Tedion	EC, WP, smokes	M	NT	L	>10,000	<10,000	Caution
thiodicarb (Rhone-Poulenc)	Larvin	DF, F, WP	M	M	L	166	>2,000	Warning
tralomethrin (Hoechst-Roussel)	Scout	EC, S, ULV	VH	H	L	1,250	>2,000	Caution
trichlorfon (Miles, NOR-AM, Tuco)	many	many	H	L	H	250	>2,100	Warning
trimethacarb (Drexel)	Broot	G	H	M	L	125	>2,000	Caution

[a]Formulations: A = aerosol; B = bait; D = dust; DF = dry flowable; EC = emulsifiable concentrate; EL = emulsifiable liquid; F = flowable; G = granules; RTU = ready to use; S = solution; SC = soluble concentrate; SL = soluble liquid; SP = soluble powder; ULV = ultra-low-volume preparation; WP = wettable powder.
[b]Toxicity to fish, bees, and birds: VL = very low; L = low; M = moderate; H = high; VH = very high; NT = no evidence of acute or chronic toxicity.
[c]LD_{50} is based on technical grade, not formulated product.
[d]Use pattern precludes exposure to the environment.
[e]TLV, threshold limit value.

18 The Toxicity of Herbicides

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Toxicity is the capacity of a substance to produce injury. Toxic effect can be immediate (acute) or accumulative (chronic), depending upon the exposure duration, the dose, and the herbicide. The toxicity of a substance varies with the animal species, age, sex, and nutritional status and with the route of exposure—through the stomach (orally), the lungs (by inhalation), or the skin (dermally). Skin and eyes are also subject to irritation caused by chemicals.

Human Toxicity of Herbicides

Pesticide manufacturers are required to conduct acute, subacute, and chronic toxicity tests, including tests for mutagenicity, teratogenicity, and carcinogenicity. The usual expression of acute toxicity is the LD_{50}, which is the average lethal dose in milligrams per body weight in kilograms required to kill 50 percent of a test population. Toxicity tests are conducted on experimental animals such as white rats, mice, or rabbits.

To make mg/kg more meaningful, the following conversion factors are given to convert mg/kg to ounces per pounds (for a 100-pound person and a 187-pound person):

mg/kg x 0.0016 = ounces/100 pounds
mg/kg x 0.0030 = ounces/187 pounds

Because toxicity depends upon body weight, the amount of chemical considered lethal for a child is less than the amount for an adult. And conversely, it takes more to kill a large animal than a small one.

The classes of toxicity are given in Table 1. The herbicide label will indicate the extent of toxicity by the signal word it carries.

Danger-Poison

Herbicides with the active ingredients endothall or paraquat carry the signal word "Danger" plus a skull and cross-bones. Endothall is available in liquid form as Endothall Turf (1.25), Aquathol K (3S), and as Hydrothol 191 (2S). Paraquat is available as ICI's Gramoxone Extra.

These herbicide labels carry the following precautions: The user is advised to wear goggles or a face shield as well as rubber gloves and a rubber apron when working with concentrates. Avoid breathing spray mists.

Danger-Corrosive

These signal words indicate the risk of irreversible eye or skin burns. This warning is usually accompanied by a recommendation for the use of goggles or a face shield, especially when the user is handling concentrates. The label may also call for rubber gloves and an apron when the user is handling or mixing concentrates or adjusting equipment. The first aid

Table 1. Toxicity Classes of Herbicides

Toxicity class	Label signal words	Acute oral LD_{50} (mg/kg)	Acute dermal LD_{50} (mg/kg)	Acute inhalation LC_{50}* (mg/liter)
High	Danger-Poison	<50	<200	<0.2
Moderate	Warning	50 to 500	200 to 2,000	0.2 to 2
Low	Caution	500 to 5,000	2,000 to 20,000	2 to 20
Very low	Caution	5,000+	20,000+	20+

*LC_{50} = concentration of pesticide, in mg/liter of air space, required to kill 50 percent of a test population.

statement says: "In case of contact with eyes, immediately flush eyes with plenty of water for at least 15 minutes and **get medical attention promptly.**" If the contact is with the skin, the label calls for washing the skin with plenty of water. If skin irritation occurs, medical attention should be sought. Herbicides in this category are:

Trade name	Common name
Aquathol 7G	endothall
Assure II	quizalofop
Balan 1.5EC	benefin
Blazer 2S	acifluorfen
Bronco 4WDL	alachlor + glyphosate
Butoxone 200	2,4-DB
Butyrac 200	2,4-DB
Cobra 2E	lactofen
Curtail 2.4S	clopyralid + 2,4-D
Devrinol 2E	napropamide
Endothal Turf 1.25	endothall
Formula 40	2,4-D amine
Galaxy 3.67S	acifluorfen + bentazon
Garlon 3A	triclopyr amine
Gordon's Brush Killer	2,4-D + mecoprop + dicamba
Hi-Dep	2,4-D
Hydrothal 191	endothall
Krovar I 80DG	bromacil + diuron
Laddok 3.33L	bentazon + atrazine
Lasso 4EC	alachlor
Option II	fenoxaprop-p-ethyl
Passport 2.6E	imazethapyr + trifluralin
Pramitol 25E	prometon
Scepter O.T. 2.5 EC	imazaquin + acifluorfen
Squadron 2.33L	imazaquin + pendimethalin
Storm 4S	acifluorfen + bentazon
Sutazine+ 6ME	butylate + atrazine
Velpar 90WSP, 2L, ULW	hexazinone
Weedar 64, 64A	2,4-D amine
Weedone 638	2,4-D amine + ester

Warning

Warning is the signal word used for herbicides containing an active ingredient which is moderately toxic through oral, dermal, or inhalation exposure. These herbicide labels state the following under Human Precautions: "May be fatal or harmful if swallowed, inhaled, or absorbed through the skin."

Cyanazine
Bladex 4L, 90DF
Extrazine II 4L, 90DF

Bromoxynil
Buctril

Diquat
Diquat

"Warning" also appears as a signal word for herbicides with label statements indicating that they can cause eye or skin irritation or burns, or may be harmful if swallowed, inhaled, or absorbed through the skin. Herbicides in this category are listed below and on the following page.

Most of these herbicide labels state: "Do not get into eyes or on skin." If skin or eye contact occurs, they call for washing the contacted areas thoroughly for 15 minutes and for calling a physician if eye contact occurs. Some herbicide labels recommend the use of goggles or face shield and other protective clothing. Fusilade, Goal, and Laddok labels specify the use of goggles or face shield. Dual, Fusilade, and Laddok labels also call for the use of rubber gloves.

Trade name	Common name
Acclaim 1EC	fenoxaprop
Acme Super Brush	2,4-D + dicamba + dichlorprop
Alanap 2L	naptalam
Banvel 4S	dicamba
Command 4EC	clomazone
Commence 5.25E	clomazone + trifluralin
Freedom	alachlor + trifluralin
Frontier	SAN 582H
Goal 2EC	oxyfluorfen
Harness	acetochlor
Horizon	fenoxaprop
Hyvar X-L 2WSL	bromacil
Krenite 4S, UT	fosamine
Lariat	alachlor + atrazine
Lasso II 15G	alachlor
Lorox Plus 60DF	linuron + chlorimuron
Poast 1.5E	sethoxydim
Poast Plus	sethoxydim
Ramrod 4F, 20G	propachlor
Ramrod/Atrazine 4L	propachlor + atrazine
Reflex 2LC	fomesafen
Rodeo 5.4S	glyphosate
Ronstar 2.5G	oxadiazon
Roundup 4S	glyphosate
Sonalan 3EC	ethalfluralin
Surpass	acetochlor
Treflan 4EC	trifluralin
Tri-Scept 3E	trifluralin + imazaquin

A chemical that does not have a "Danger" or "Warning" signal word will have "Caution" on the label. "Caution" indicates that the product has low oral, dermal, and inhalation toxicity and has little or no irritability to either the eyes or the skin.

Environmental Toxicity of Herbicides

The Environmental Hazards section of the label includes statements regarding toxicity to fish and wildlife; and, the user has to be especially careful. Herbicides that state that they are toxic to fish or wildlife contain the active ingredients bromoxynil, propachlor, or others.

Bromoxynil
- Bronate
- Buctril
- Buctril/Atrazine

Propachlor
- Ramrod 4F
- Ramrod/Atrazine

Other
- Diquat (diquat)
- Goal (oxyfluorfen)
- Gramoxone Extra (paraquat)
- Pramitol (prometon)

Some herbicide labels carry the statement "Toxic to Fish." These include certain esters of phenoxy and pyridinoxy-phenoxy herbicides, the dinitroaniline herbicides, and miscellaneous others. All herbicide labels warn the user to keep the product out of lakes and streams.

*Phenoxy esters**
- Butoxone ester
- Butyrac ester
- Crossbow
- Esteron 44, 99
- Weedone 170
- Weedone LV

Oxy-phenoxy esters
- Fusilade (fluazifop)
- Hoelon (diclofop)
- Option (fenoxaprop)
- Verdict (haloxyfop)

Dinitroanilines (DNAs)
- Balan (benefin)
- Prowl (pendimethalin)
- Sonalan (ethalfluralin)
- Treflan (trifluralin)

DNA mixes
- Commence (trifluralin + clomazone)
- Passport (trifluralin + imazethapyr)
- Pursuit Plus (pendimethalin + imazethapyr)
- Salute (trifluralin + metribuzin)
- Squadron (pendimethalin + imazaquin)
- Tri-Scept (trifluralin + imazaquin)

The potential for the contamination of groundwater with pesticides has prompted the addition of groundwater statements on several pesticide labels, especially those products containing atrazine, simazine, alachlor, metolachlor, or metribuzin. The following herbicides carry label statements cautioning the user to handle the herbicides in a manner that will minimize the potential for groundwater contamination.

Trade name	Common name
AAtrex, Atrazine	atrazine
Access	picloram + 2,4-D
Arena	alachlor
Bicep	atrazine + metolachar
Bladex	cyanazine
Bronco	alachlor + glyphosate
Buctril/Atrazine	bromoxynil + atrazine
Bullet	atrazine + alachlor
Canopy	metribuzin + chlorimuron
Confidence	alachlor
Cycle	metolachlor + cyanazine
Dual	metolachlor
Extrazine II	cyanazine + atrazine
Freedom	alachlor + trifluralin
Griffex	atrazine
Judge	alachlor
Laddok	atrazine + bentazon
Lariat	atrazine + alachlor
Lasso	alachlor
Lexone	metribuzin
Pennant	metolachlor
Preview	metribuzin + chlorimuron
Princep	simazine
Ramrod/Atrazine	propachlor + atrazine
Saddle	alachlor
Salute	trifluralin + metribuzin
Sencor	metribuzin
Sim-Trol	simazine
Stall	alachlor
Stinger	clopyralid
Tordon K	picloram
Tordon RTU	picloram + 2,4-D
Tordon 101 Mixture	picloram + 2,4-D
Turbo	metribuzin + metolachlor

*There are many phenoxy herbicide products.

19

Herbicide Formulations and Toxicities

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You should consider the potential health problems of a herbicide when you are choosing products. As you look through Table 1, you will see that products differ in their toxicity, and even various formulations of one active ingredient may differ in their oral or dermal toxicity or their irritability to the skin or eyes. The data correspond with the specific formulation listed under the trade name; for example, information for the three AAtrex products is given under AAtrex across from 80W, 4L, and Nine-O. In a few instances, no information is available for the specific formulation. In these cases, data have been included for the active ingredient; this information has been listed across from the common name rather than the formulation (for example, Casoron).

The toxicity information given here is for acute (one-time) exposure. Acute exposure is what you receive during one application or one day's work with a product. You should not extrapolate your risk of chronic disease (exposure over a lifetime or many years) from acute toxicity data.

The label signal word (DANGER, Warning, or Caution) gives you a general idea of the hazard of the product. The signal word is always triggered by the category that most seriously threatens your health. For example, a chemical with a low oral and dermal toxicity, which would have "Caution" on the label, would instead have the signal word "DANGER" if it is corrosive to the eyes. In fact, several herbicides with low oral toxicity can be hazardous because of their risk to skin or eyes. The label signal word of "Warning" or "DANGER" is a clue to look closely at the precautionary statements on the label. For more information on toxicity and how toxicity tests are conducted, see Chapter 18, "The Toxicity of Herbicides."

Material safety data sheets (MSDS), which are available from the product manufacturer or your pesticide dealer, contain information on other characteristics of a herbicide that might influence your handling of the product. In addition to these resources, you can contact the herbicide manufacturer if you have questions about the product.

Table 2 gives the common name of an active ingredient with the corresponding trade names of products that contain that active ingredient. Some products contain only one active ingredient; others contain two or more. Premixes are indicated with an asterisk following the trade name.

As active ingredients go off patent, additional products containing the same active ingredients become available to the public as either private or generic brands. Private brands are manufactured by a producer of the active ingredient but distributed by another company. The quality and toxicity of a private brand should be identical to that of the original product of the same formulation. Therefore, the private brands are listed in Table 2 under the active ingredient but are not listed in Table 1. Refer to the toxicity of the original product, but be sure to look under the appropriate formulation.

Generic brands contain an active ingredient component found in a commonly known product, but the active ingredient for the formulation may be obtained from a different manufacturer. In addition, inert ingredients in the formulation (emulsifiers, for example) may be different. Generic brands are listed in Table 2 under the active ingredient, and their toxicity data can be found in Table 1.

The majority of products listed in these two tables are currently labeled and commonly used. As new products near time of release to the public (if expected in the following use season), they are included in these lists, though they may not be immediately available. Likewise, a product that has been suspended but is still available (supplies have yet to be depleted) has been kept on these lists. If you have a question about the availability of a herbicide, consult the product manufacturer or the appropriate chapter in this handbook for pesticide use recommendations.

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

Table 1. Toxicity Information and Label Signal Words

Trade name and formulation[a]	Common name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
AAtrex*§	atrazine					
80W	*Ciba-Geigy*	5,100	9,300	Moderate	Mild	Caution
4L		1,075	> 5,000	Mild	Mild	Caution
Nine-O (90WDG)		1,600	>10,000	Mild	Mild	Caution
Accent	nicosulfuron					
75WDG	*DuPont*	> 5,000	> 2,000	Mild	Moderate	Caution
Access*§	triclopyr + picloram					
3E	(2 + 1 lb) *DowElanco*	2,525	> 2,000	Moderate	Moderate	Caution
Acclaim	fenoxaprop					
1EC	*Hoechst*	> 3,310	> 2,000	Mild	Moderate	Warning
Acme Super Brush Killer	2,4-D + dichlorprop + dicamba					
4.5E	(2 + 2 + 0.05 l) *PBI Gordon*	> 1,200	> 2,000	Mild	Moderate	Warning
Alanap-L	naptalam					
2EC	*Uniroyal*	1,770	>20,000	Mild	Moderate	Warning
Ally	metsulfuron methyl					
60DF	*DuPont*	> 5,000	> 2,000	Mild	Mild	Caution
Amitrol-T*	amitrole					
2S	*Rhone-Poulenc*	10,480	>10,000	Moderate	Moderate	Caution-(carcinogenic)
Amizol*	amitrole					
90WSP	*Rhone-Poulenc*	14,700	>10,000	None	Slight	Caution-(carcinogenic)
Aquathol	endothall					
K (3S)	*Atochem*	125	171	Severe	Severe-Corrosive	DANGER-Poison
7G		1,340	>10,000	Moderate	Severe-Corrosive	DANGER
Arsenal	imazapyr					
2L	*American Cyanamid*	> 5,000	> 2,148	Mild	Mild	Caution
A.C. 4S		> 5,000	> 2,000	Mild	None	Caution
Arsonate	MSMA					
6.6S	*ISK Biotech*	1,700	2,500	Mild	Mild	Caution
Assure II	quizalofop					
0.88EC	*DuPont*	4,100	> 2,000	Moderate	Severe	DANGER
Asulox	asulam					
3.34S	*Rhone-Poulenc*	> 8,000	> 1,000	Mild	Mild	Caution

Table 1. Toxicity Information and Label Signal Words (cont.)

Trade name and formulation[a]	Common name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
Balan	benefin					
1.5EC	*DowElanco*	> 500	> 2,000	Moderate	Severe	DANGER
2.5G		> 2,500	> 5,000	Slight	Moderate	Caution
60DF		> 500	> 2,000	Moderate	Moderate	Caution
Banvel	dicamba					
4S	*Sandoz*	2,629	> 2,000	Moderate	Severe	Warning-Corrosive
Banvel 720	dicamba + 2,4-D					
3S	(1 + 2 lb) *Sandoz*	2,500	...	...	Moderate	Caution
Barricade	prodiamine					
65WDG	*Sandoz*	> 5,000	> 2,000	None	Mild	Caution
Basagran	bentazon					
4S	*BASF*	1,860	> 2,450	Moderate	Moderate	Caution
Beacon	primisulfuron					
75WDG	*Ciba-Geigy*	> 5,050	> 2,010	Slight	Mild	Caution
Betasan	bensulide					
3.6G	*ICI Americas*	> 1,000	> 5,000	None	Moderate	Caution
7G		3,549	> 2,000	None	Moderate	Warning
12.5G		1,987	> 2,000	None	Moderate	Warning
4E		1,115	> 2,000	Mild	Severe	Caution
2.9E		1,420	> 2,000	Mild	Moderate	Caution
Bicep*§	metolachlor + atrazine					
6L	(3.33 + 2.67 lb) *Ciba-Geigy*	4,060	> 2,010	Moderate	Moderate	Caution
Bicep Lite*§	metolachlor + atrazine					
5L	(3.3 + 1.7 lb) *Ciba-Geigy*	3,030	> 2,020	Mild	Mild	Caution
Bladex*§	cyanazine					
90DF	*DuPont*	266	> 2,000	Mild	Moderate	Warning
4L		473	> 2,000	Slight	Mild	Warning
Blazer	acifluorfen					
2S	*BASF*	4,790	3,250	Moderate	Severe	DANGER
Bronco*§	alachlor + glyphosate					
4WDL	(2.6 + 1.4 lb) *Monsanto*	3,152	> 5,000	Slight	Severe	DANGER
Buctril	bromoxynil					
2EC	*Rhone-Poulenc*	780	> 2,000	Moderate	Moderate	Warning

Table 1. Toxicity Information and Label Signal Words (cont.)

Trade name and formulation[a]	Common name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
Buctril + Atrazine*§ 3WDL	bromoxynil + atrazine (1 + 2 lb) *Rhone-Poulenc*	3,600	> 2,000	None	Moderate	Caution
Bullet 4MT *§ 4ME	alachlor + atrazine (2.5 + 1.5 lb) *Monsanto*	8,900	> 5,000	Slight	Slight	Caution
Butyrac 200 2EC	2,4-DB *Rhone-Poulenc*	1,706	1,440	Moderate	Severe	DANGER-Corrosive
Butoxone 200 2EC	2,4-DB *Cedar*	1,706	1,440	Moderate	Severe	DANGER-Corrosive
Canopy§ 75WDG	metribuzin + chlorimuron (64.3% + 10.7%) *DuPont*	1,500	> 2,000	Slight	Mild	Caution
Casoron	dichlobenil *Uniroyal*	> 3,200	> 2,000	Mild	Mild	
50W						Caution
4G						Caution
10G		> 5,000	> 2,000	None	Moderate	Caution
Chipco Turf 2EC	mecoprop (MCPP) *Rhone-Poulenc*	930	900	Moderate	Moderate	Caution
Classic 25DF	chlorimuron *DuPont*	> 5,000	> 2,000	Mild	Mild	Caution
Cobra 2E	lactofen *Valent*	2,530	> 2,000	Severe	Severe	DANGER
Command 4EC	clomazone *FMC*	2,235	> 2,000	Mild	Moderate	Warning
Commence 5.25EC	trifluralin + clomazone (3 + 2.25 lb) *DowElanco and FMC*	> 500	> 5,000	Moderate	Moderate	Warning
Crossbow 3EC	triclopyr + 2,4-D (1 + 2 lb) *DowElanco*	1,792	1,796	Mild	Slight	Caution
Curtail 2.4S	clopyralid + 2,4-D (0.38 + 2 lb) *DowElanco*	> 2,830	> 4,000	Moderate	Severe	DANGER
Cycle*§ 4EC	metolachlor + cyanazine (2 + 2 lb) *Ciba-Geigy*	1,260	> 2,010	Moderate	Mild	Caution

Table 1. Toxicity Information and Label Signal Words (cont.)

Trade name and formulation[a]	Common name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
Dacthal	DCPA					
75WP	*ISK Biotech*	>10,000	>10,000	None	Moderate	Warning
Devrinol	napropamide					
50WP	*ICI Americas*	2,710	> 4,640	Mild	Mild	Caution
10G		> 5,000	> 5,000	None	None	Caution
5G		> 5,000	> 5,000	None	Moderate	Caution
2G		> 5,000	> 5,000	None	Moderate	Caution
2E		3,690	> 5,000	Moderate	Severe	DANGER-Corrosive
Dimension	dithiopyr					
1EC	*Monsanto*	> 360	> 5,000	Mild	Severe	Warning
Diquat	diquat					
2S	*Valent*	230	> 400	Moderate	Moderate	Warning
Direx	diuron					
4L	*Griffin*	> 3,400	> 2,000	Mild	Moderate	Caution
Dual§	metolachlor					
8E	*Ciba-Geigy*	> 820	> 5,009	Slight	Mild	Caution
25G		> 5,000	> 2,000	Mild	Slight	Caution
Endothal Turf	endothall					
1.2S	*Atochem*	198	> 2,000	Severe-Corrosive	Severe-Corrosive	DANGER
Eptam	EPTC					
7E	*ICI Americas*	1,325	2,750	Mild	Moderate	Caution
10G		> 5,000	> 5,000	None	Moderate	Caution
Eradicane	EPTC + safener					
6.7E	*ICI Americas*	> 2,000	3,830	Mild	Severe	Caution
Eradicane Extra	EPTC + safener					
6E	+ extender *ICI Americas*	776	> 2,000	Mild	Moderate	Caution
Escort	metsulfuron methyl					
60DF	*DuPont*	> 5,000	> 2,000	Mild	Mild	Caution
Evik	ametryn					
80WP	*Ciba-Geigy*	1,950	> 3,100	Mild	Mild	Caution
Extrazine II*§	cyanazine + atrazine					
90DF	(67.5% + 22.5%)	369	> 2,000	Mild	Mild	Warning
4L	(3 + 1 lb) *DuPont*	366	> 2,200	Slight	Mild	Warning
Freedom*§	alachlor + trifluralin					
3EC	(2.67 + 0.33 lb) *Monsanto*	2,650	> 5,000	Severe	Severe	Warning

Table 1. Toxicity Information and Label Signal Words (cont.)

Trade name and formulation[a]	Common name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
Frontier 7.5L	San 582H *Sandoz*	2,400	> 2,000	Slight	Severe	Warning
Fusilade 2000 1EC	fluazifop-p-butyl *ICI Americas*	4,350	> 2,000	Mild	Mild	Caution
Fusion 2.56EC	fluazifop + fenoxaprop-p-ethyl (2.0 + 0.56 lb) *ICI Americas*	3,154	> 2,000	Moderate	Moderate	Caution
Galaxy 3.67S	acifluorfen + bentazon (1:4.5) (0.67 + 3.0 lb) *BASF*	> 1,210	> 2,000	Moderate	Severe	DANGER
Gallery 75DF	isoxaben *DowElanco*	> 5,000	> 5,000	Moderate	Moderate	Caution
Garlon	triclopyr *DowElanco*					
3A		1,847	> 3,980	Moderate	Severe	DANGER
4E		1,338	2,315	Moderate	Mild	Caution
Goal 2EC	oxyfluorfen *Rohm & Haas*	5,800	> 3,000	Moderate	Moderate	Warning
Gordon's Brush Killer 4E	2,4-D + mecoprop + dicamba (2 + 1 + 1 lb) *Gordon*	> 1,550	> 2,010	Moderate	Corrosive	DANGER
Gramoxone Extra* 2.5S	paraquat *ICI Americas*	30	240	Severe	Severe	DANGER-Poison
Harmony Extra 75DF	thifensulfuron methyl + tribenuron methyl (50% + 25%) *DuPont*	> 5,000	> 2,000	Mild	Moderate	Caution
Harness 4ME	acetochlor *Monsanto*	2,676	> 5,000	Moderate	Severe	Warning
Hi-Dep 4E	2,4-D *PBI Gordon*	2,621	> 2,000	Moderate	Severe	DANGER
Hoelon* 3EC	diclofop-methyl *Hoechst*	2,176	640	Moderate	Moderate	DANGER (possible carcinogen)
Horizon 1EC	fenoxaprop *Hoechst*	> 3,310	> 2,000	Mild	Moderate	Warning

Table 1. Toxicity Information and Label Signal Words (cont.)

Trade name and formulation[a]	Common name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
Horizon 2000	fluazifop + fenoxaprop-p-ethyl					
2.56EC	(2.0 + 0.56 lb) *Hoechst*	3,154	> 2,000	Moderate	Moderate	Caution
Hydrothal 191	endothall					
2S	*Atochem*	221	50	Severe	Severe-Corrosive	DANGER-Poison
5G		1,540	>10,000	Moderate	Severe-Corrosive	DANGER
Hyvar	bromacil					
X (80WP)	*DuPont*	> 5,000	> 5,000	Moderate	Slight	Caution
X-L (2WSL)		1,414	> 2,000	Moderate	Moderate	Warning
Karmex	diuron					
80DF	*DuPont*	6,964	> 2,000	None	Moderate	Warning
Kerb*	pronamide					
50WP	*Rohm & Haas*	5,620	> 3,160	Mild	Slight	Caution
Kleenup	glyphosate					
0.5S	*Ortho*	5,600	> 5,000	Slight	Slight	Caution
Krenite S	fosamine					
4S	*DuPont*	> 5,000	> 5,000	Mild	Moderate	Warning
Krenite UT	fosamine					
4S	*DuPont*	> 5,000	> 5,000	Mild	Moderate	Warning
Krovar I	bromacil + diuron					
80DF	(40% + 40%) *DuPont*	> 2,500	> 2,000	Severe	Mild	DANGER
Krovar II	bromacil + diuron					
80DF	(53% + 27%) *DuPont*	3,816	> 2,000	Moderate	Moderate	Caution
Laddok*§	bentazon + atrazine					
3.33L	(1.67 + 1.67 lb) *BASF*	3,340	> 5,000	Moderate	Moderate	DANGER-Corrosive
Lariat*§	alachlor + atrazine (5:3)					
4F	(2.5 + 1.5 lb) *Monsanto*	4,400	> 5,000	Severe	Moderate	Warning
Lasso*§	alachlor					
II (15G)	*Monsanto*	5,800	16,000	Slight	Severe	Warning
4EC		2,000	7,800	Moderate	Severe	DANGER

Table 1. Toxicity Information and Label Signal Words (cont.)

Trade name and formulation[a]	Common name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
Lentagran	pyridate					
45WP	*Agrolinz*	2,205	> 2,000	None	Mild	Caution
Lexone§	metribuzin					
4L	*DuPont*	2,890	> 7,500	None	Moderate	Caution
75DF		2,795	>20,000	None	Moderate	Caution
Linex	linuron					
4L	*Griffin*	2,437	> 2,000	None	Slight	Caution
50DF		4,833	> 2,000	Mild	Mild	Caution
Lorox	linuron					
4L	*DuPont*	2,437	> 2,000	None	Slight	Caution
50DF		4,833	> 2,000	None	Mild	Caution
Lorox Plus	chlorimuron + linuron (1:16)					
60DF	(3% + 57%) *DuPont*	1,800	> 2,000	Moderate	Severe	Warning
Marksman*§	dicamba + atrazine					
3.2F	(1.1 + 2.1 lb) *Sandoz*	5,900	> 2,000	Mild	Mild	Caution
Micro Tech	alachlor					
4ME	*Monsanto*	> 5,000	> 5,000	Mild	Mild	Caution
Norosac	dichlobenil					
50W	*PBI Gordon*	> 6,210	> 2,000	Mild	Mild	Caution
4G		> 3,160	> 2,000	Mild	Mild	Caution
10G		> 3,160	1,350	Mild	Moderate	Caution
Option II*	fenoxaprop-p-ethyl					
0.79EC	*Hoechst*	3,250	> 2,000	Mild	Severe	DANGER
Oust	sulfometuron methyl					
75DG	*DuPont*	> 5,000	> 2,000	None	Mild	Caution
Passport	trifluralin + imazethapyr					
2.6EC	(2.4 + 0.2 lb) *American Cyanamid*	3,674	> 2,000	Mild	Severe-Irreversible	DANGER
Pathway	picloram + 2,4-D					
1.3S	(0.3 + 1.0 lb) *DowElanco*	> 5,000	> 3,980	Moderate	Moderate	Warning
Pennant§	metolachlor					
5G	*Ciba-Geigy*	> 5,030	> 2,010	Mild	Slight	Caution
Pinnacle	thifensulfuron methyl					
25DF	*DuPont*	> 5,000	> 2,000	None	Moderate	Caution

Table 1. Toxicity Information and Label Signal Words (cont.)

Trade name and formulation[a]	Common name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
Poast 1.5E	sethoxydim *BASF*	4,900	> 4,000	Moderate	Moderate	Warning
Poast Plus 1E	sethoxydim *BASF*	> 2,200	> 2,000	Moderate	Moderate	Caution
Pondmaster 5.4S (4 a.e.)	glyphosate *Monsanto*	> 5,000	> 5,000	Mild	None	Warning
Pramitol 25E 2EC	prometon *Ciba-Geigy*	2,110	2,000	Severe	Corrosive	DANGER-Corrosive
Predict 80WDG	norflurazon *Sandoz*	3,240	>20,000	None	None	Caution
Prefar 4E	bensulide *ICI Americas*	826	> 4,640	Mild	Moderate	Caution
Preview§ 75DF	chlorimuron + metribuzin (7.5% + 67.5%) *DuPont*	1,500	2,000	None	Moderate	Caution
Princep§ 4L	simazine *Ciba-Geigy*	> 5,000	> 2,500	Slight	Slight	Caution
80W		>15,380	>10,200	Mild	Mild	Caution
4G		> 5,070	> 2,010	Slight	Mild	Caution
90WDG		> 5,000	> 2,000	Slight	Slight	Caution
Prowl 3.3EC	pendimethalin *American Cyanamid*	3,956	> 2,200	Mild	Mild	Caution
Pursuit 2EC	imazethapyr *American Cyanamid*	> 5,000	> 2,000	Mild	None	Caution
Pursuit Plus 3EC	imazethapyr + pendimethalin (1:14) (0.2 + 2.8 lb) *American Cyanamid*	> 5,000	> 2,000	Mild	None	Caution
Ramrod 4F	propachlor *Monsanto*	3,269	4,194	Severe-Corrosive	Moderate	Warning
20G		4,000	>20,000	Slight	Severe-Corrosive	Warning
Ramrod/Atrazine*§ 4L	propachlor + atrazine (3 + 1 lb) *Monsanto*	2,374	> 5,000	Slight	Moderate	Warning
Reflex 2LC	fomesafen *ICI Americas*	> 5,000	> 2,000	Mild	Moderate	Warning-(carcinogenic)

Table 1. Toxicity Information and Label Signal Words (cont.)

Trade name and formulation[a]	Common name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
Rifle	primisulfuron					
75WDG	*Ciba-Geigy*	> 5,050	> 2,010	Slight	Mild	Caution
Rodeo	glyphosate					
5.4S (4 a.e.)	*Monsanto*	> 5,000	> 5,000	Mild	None	Warning
Ronstar	oxadiazon					
2.5G	*Rhone-Poulenc*	> 5,000	> 2,000	Moderate	Mild	Warning
50WP		> 5,000	> 2,000	Severe	Moderate	Warning
Roundup	glyphosate					
4S (3 a.e.)	*Monsanto*	5,400	> 5,000	Moderate	Slight	Warning
Salute§	metribuzin + trifluralin					
4E	(1.33 + 2.67 lb) *Mobay*	1,561	> 2,000	Mild	Mild	Caution
Scepter	imazaquin					
1.5EC	*American Cyanamid*	> 5,000	> 5,000	Mild	Mild	Caution
70DG		6,156	> 2,000	None	Mild	Caution
Scepter O.T.	imazaquin + acifluorfen					
2.5EC	(0.5 + 2.0 lb) *American Cyanamid*	3,078	> 2,000	Mild	Severe	DANGER
Select	clethodim					
2EC	*Valent*	2,920	> 5,000	Moderate	Moderate	Warning
Sencor§	metribuzin					
4L	*Mobay*	> 1,500	>20,000	None	None	Caution
75DF		2,379	> 5,000	Slight	Moderate	Caution
Sinbar	terbacil					
80WP	*DuPont*	> 5,000	> 5,000	None	Mild	Caution
Snapshot	isoxaben + oryzalin					
80DF	(20% + 60%) *DowElanco*	> 5,000	5,000	Mild	Mild	Caution
Snapshot	isoxaben + trifluralin					
2.5TG	(0.5% + 2%) *DowElanco*	> 2,500	5,000	Slight	Mild	Caution
Sonalan	ethalfluralin					
3EC	*DowElanco*	>10,000	> 2,000	Moderate	Moderate	Warning
Sonar	fluridone					
4AS	*DowElanco*	> 1,500	> 2,000	Moderate	Slight	Caution
5P (5%)		> 500	> 2,000	None	Moderate	Caution
5SRP (5%)		> 500	> 2,000	None	Moderate	Caution

Table 1. Toxicity Information and Label Signal Words (cont.)

Trade name and formulation[a]	Common name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
Spike	tebuthiuron					
20P	*DowElanco*	> 500	> 2,000	None	Moderate	Warning
40P		> 500	> 2,000	Slight	Moderate	Caution
80W		> 500	> 2,000	None	Slight	Caution
80WSP		> 500	> 2,000	None	Slight	Caution
Spike-Treflan	tebuthiuron + trifluralin					
6G	(2% + 4%) *DowElanco*	> 500	> 2,000	Moderate	Moderate	Caution
Squadron	pendimethalin + imazaquin (6:1)					
2.33L	(2.0 + 0.33 lb) *American Cyanamid*	3,695	> 2,000	Mild	Severe	DANGER
Stinger§	clopyralid					
3S	*DowElanco*	> 5,000	> 5,000	Mild	Slight	Caution
Stomp	pendimethalin					
3.3EC	*American Cyanamid*	3,956	2,200	Mild	Mild	Caution
Storm	acifluorfen + bentazon					
4S	(1.33 + 2.67 lb) *BASF*	> 1,470	> 2,000	None	Severe	DANGER
Surflan	oryzalin					
4AS	*DowElanco*	>10,000	> 2,000	Slight	Mild	Caution
Surpass	acetochlor + safener					
6.4EC	*ICI Americas*	1,426	> 2,240	Moderate	Moderate	Warning
Sutan+	butylate					
6.7E	*ICI Americas*	3,690	> 4,640	Moderate	Moderate	Caution
Sutazine+*§	butylate + atrazine					
18:6G	(18 + 6 lb)	> 5,000	> 5,000	None	None	Caution
6ME	(4.8 + 1.2 lb) *ICI Americas*	3,200	> 2,000	Moderate	Severe	DANGER-Corrosive
Team	trifluralin +					
2G	benefin *DowElanco*	500	> 2,000	None	Moderate	Caution
Telar	chlorsulfuron					
75DF	*DuPont*	2,341	> 3,400	None	Mild	Caution
Thistrol	MCPB					
2S	*Rhone-Poulenc*	680	...	Severe	Severe-Corrosive	Caution
Tordon 101 Mixture*§	picloram + 2,4-D					
2.5S	(0.5 + 2.0 lb) *DowElanco*	2,598	> 2,000	Moderate	Moderate	Caution

Table 1. Toxicity Information and Label Signal Words (cont.)

Trade name and formulation[a]	Common name[b] and producer	Acute LD_{50} Oral[c]	Acute LD_{50} Dermal[d]	Irritation Dermal[e]	Irritation Eye[f]	Label signal word
Tordon K*§	picloram					
2S	*DowElanco*	> 5,000	> 2,000	Slight	Moderate	Caution
Tordon RTU	picloram + 2,4-D					
1.3S	(0.3 + 1.0 lb) *DowElanco*	> 5,000	> 3,980	Moderate	Moderate	Warning
Touchdown	sulfosate					
6L	*ICI Americas*	750	> 2,000	Mild	Mild	Caution
Tough	pyridate					
3.75EC	*Agrolinz*	905	> 2,000	Slight	Mild	Caution
Transline	clopyralid					
3S	*DowElanco*	> 5,000	> 5,000	Mild	Slight	Caution
Treflan	trifluralin					
4EC	*DowElanco*	> 500	> 2,000	Moderate	Moderate	Warning
4MTF		> 5,000	> 2,000	Moderate	Moderate	Caution
5G		> 500	> 2,000	None	Moderate	Caution
5EC		> 500	> 2,000	Moderate	Moderate	Caution
80 D.C. (80DF)		...	> 2,000	Moderate	Moderate	Caution
Tri-4	trifluralin					
4EC	*American Cyanamid*	> 500	> 2,000	Moderate	Moderate	Warning
Trific	trifluralin					
60DF	*Terra*	> 5,500	> 2,200	Mild	Severe	DANGER
Trilin	trifluralin					
4EC	*Griffin*	> 500	>2,000	Moderate	Moderate	Warning
Tri-Scept	imazaquin + trifluralin (1:6)					
3EC	(0.43 + 2.6 lb) *American Cyanamid*	4,330	> 2,000	Mild	Moderate	Warning
Tupersan	siduron					
50WP	*DuPont*	7,500	> 5,500	None	Mild	Caution
Turbo§	metribuzin + metolachlor					
8EC	(1.45 + 6.55 lb) *Mobay*	849	> 2,000	Slight	Slight	Caution
Turflon D	triclopyr + 2,4-D					
3EC	(1 + 2 lb) *DowElanco*	1,792	1,796	Mild	Slight	Caution
Velpar	hexazinone					
90WSP	*DuPont*	860	> 5,278	None	Severe	DANGER
2L		6,887	> 7,500	None	Severe	DANGER
ULW (75G)		1,200	> 2,000	None	Moderate	DANGER

Table 1. Toxicity Information and Label Signal Words (cont.)

Trade name and formulation[a]	Common name[b] and producer	Acute LD_{50}		Irritation		Label signal word
		Oral[c]	Dermal[d]	Dermal[e]	Eye[f]	
Weedar 64 3.8S	2,4-D dimethylamine *Rhone-Poulenc*	1,150	1,530	Mild	Severe-Corrosive	DANGER-Corrosive
Weedar 64A 3.8S	2,4-D diethanolamine *Rhone-Poulenc*	2,576	> 2,000	Mild	Severe-Corrosive	DANGER-Corrosive
Weedmaster 3.8S	dicamba + 2,4-D (1 + 2.87 lb) *Sandoz*	> 5,000	...	...	Mild	Caution
Weedone 2,4-DP 4EC	dichlorprop (2,4-DP) *Rhone-Poulenc*	1,955	2,200	None	Moderate	Caution
Weedone LV4 3.8E	2,4-D ester *Rhone-Poulenc*	1,375	> 2,000	Mild	Mild	Caution
Weedone 170 3.7E	dichlorprop + 2,4-D *Rhone-Poulenc*	> 2,000	> 2,000	None	Mild	Caution
XL 2G	benefin + oryzalin (1% + 1%) *DowElanco*	3,750	> 2,000	Slight	Moderate	Caution

An ellipsis (...) indicates that the information is not available at this time.
*Restricted-use pesticide (RUP).
§Groundwater advisory.
[a]EC or E means emulsifiable concentrate; G, granule; L, flowable; S, water-soluble liquid; WDG, water-dispersible granule; WDL, water-dispersible liquid; WP or W, wettable powder; WSP, water-soluble powder; DF, dry-flowable; P, pellet; F, flowable; ME, micro-encapsulated. Liquid formulations (EC, E, L, S, WDL, F, ME) are in pounds per gallon; dry formulations (G, WDG, WP, WSP, DF, P) are in percentages.
[b]Weed Science Society of America–approved name or experimental number.
[c]Oral LD_{50} means the milligrams of chemical per kilogram of body weight that are lethal to 50 percent of a population of test animals, usually white rats, when administered in a single, oral dose.
[d]Dermal LD_{50} means the milligrams of chemical per kilogram of body weight that are lethal to 50 percent of a population of test animals, usually rabbits, when administered in a single, dermal dose.
[e]Dermal irritation is determined by applying an amount of pesticide onto the skin of shaved test animals.
[f]Eye irritation is determined by applying an amount of pesticide into the eye of test animals.

Table 2. Herbicide Active Ingredients and Products Containing These Active Ingredients

Common name	Trade name(s)
acetochlor	Harness
	Surpass (+ safener)
acifluorfen	Blazer
	Galaxy*
	Scepter O.T.*
	Storm*
alachlor	Bronco*
	Bullet*
	Confidence[a]
	Cropstar[a]
	Freedom*
	Judge[a]
	Lariat*
	Lasso
	Micro Tech
	Partner[a]
	Saddle[a]
	Stall[a]
ametryn	Evik
amitrole	Amitrol-T
	Amizol
asulam	Asulox
atrazine	AAtrex
	Bicep*
	Bicep Lite*
	Buctril + Atrazine*
	Bullet*
	Extrazine II*
	Laddok*
	Lariat*
	Marksman*
	Ramrod/Atrazine*
	Sutazine+*
benefin	Balan
	Team*
	XL*
bensulide	Betasan
	Prefar
bentazon	Ascend[b]
	Basagran
	Basic[b]
	Depend[b]
	Equal[b]
	Galaxy*
	Laddok*
bentazon (cont.)	Leader[b]
	Pacer[b]
	Pledge[b]
	Scope[b]
	Storm*
	Victor[b]
bromacil	Hyvar
	Krovar I*
	Krovar II*
bromoxynil	Buctril
	Buctril + Atrazine*
butylate	Sutan+
	Sutazine+*
chlorimuron	Canopy*
	Classic
	Gemini*
	Lorox Plus*
	Preview*
chlorsulfuron	Telar
clethodim	Select
clomazone	Command
	Commence*
clopyralid	Curtail*
	Stinger
	Transline
cyanazine	Bladex
	Cycle*
	Extrazine II*
2,4-D	Acme Super Brush Killer*
	Banvel 720*
	Crossbow*
	Curtail*
	Hi-Dep
	Pathway*
	Trimec 352*
	Tordon 101 Mixture*
	Tordon RTU*
	Turflon D*
	Weedar 64
	Weedar 64A
	Weedmaster*
	Weedone LV4
	Weedone 170*
	(many others)

Table 2. Herbicide Active Ingredients and Products Containing These Active Ingredients (cont.)

Common name	Trade name(s)
2,4-DB	Butoxone
	Butyrac 200
2,4-DP	(*see* dichlorprop)
DCPA	Dacthal
dicamba	Acme Super Brush Killer*
	Banvel
	Banvel 720*
	Marksman*
	Trimec 352*
	Weedmaster*
dichlobenil	Casoron
	Norosac
dichlorprop (2,4-DP)	Acme Super Brush Killer*
	Weedone 2,4-DP
	Weedone 170*
diclofop-methyl	Hoelon
diquat	Diquat
dithiopyr	Dimension
diuron	Direx
	Karmex
	Krovar I*
	Krovar II*
endothall	Aquathol
	Endothal Turf
	Hydrothal 191
EPTC	Eptam
	Eradicane (plus safener)
	Eradicane Extra (plus safener and extender)
ethalfluralin	Sonalan
fenoxaprop	Acclaim
	Horizon
fenoxaprop-p-ethyl	Fusion*
	Horizon 2000*
	Option II
fluazifop-p-butyl	Fusilade 2000
	Fusion*
	Horizon 2000*
fluridone	Sonar
fomesafen	Reflex
fosamine	Krenite S
	Krenite UT
glyphosate	Accord
	Bronco*
	Honcho[c]
	Jury[c]
	Kleenup
	Mirage[c]
	Pondmaster
	Protocol[c]
	Ranger
	Rascal[c]
	Rattler[c]
	Rodeo
	Roundup
	Ruler[c]
	Showoff[c]
	Silhouette[c]
hexazinone	Velpar
imazapyr	Arsenal
	Arsenal A.C.
imazaquin	Scepter
	Scepter O.T.*
	Squadron*
	Tri-Scept*
imazethapyr	Passport*
	Pursuit
	Pursuit Plus*
isoxaben	Gallery
	Snapshot 80DF*
	Snapshot 2.5TG*
lactofen	Cobra
linuron	Linex
	Lorox
	Lorox Plus*
MCPB	Thistrol
MCPP	(*see* mecoprop)
mecoprop (MCPP)	Chipco Turf
	Trimec 352*
	(many turf mixtures)
metolachlor	Bicep*
	Bicep Lite*
	Cycle*

Table 2. Herbicide Active Ingredients and Products Containing These Active Ingredients (cont.)

Common name	Trade name(s)
metachlor (cont.)	Dual Pennant Turbo*
metribuzin	Canopy* Lexone Preview* Salute* Sencor Turbo*
metsulfuron methyl	Ally Escort
MSMA	Arsonate
napropamide	Devrinol
naptalam	Alanap-L
nicosulfuron	Accent
norflurazon	Predict
oryzalin	Snapshot 80DF* Surflan XL*
oxadiazon	Ronstar
oxyfluorfen	Goal
paraquat	Gramoxone Extra
pendimethalin	Prowl Pursuit Plus* Squadron* Stomp
picloram	Access* Pathway* Tordon 101 Mixture* Tordon K Tordon RTU*
primisulfuron	Beacon Rifle
prodiamine	Barricade
prometon	Pramitol 25E
pyridate	Lentagran Tough
quizalofop	Assure II
SAN 582H	Frontier
sethoxydim	Poast Poast Plus
siduron	Tupersan
simazine	Princep
sulfometuron methyl	Oust
sulfosate	Touchdown
tebuthiuron	Spike Spike-Treflan*
terbacil	Sinbar
thifensulfuron methyl	Harmony Extra* Pinnacle
tribenuron methyl	Express Harmony Extra*
triclopyr	Access* Crossbow* Garlon Turflon D*
trifluralin	Commence* Freedom* Passport* Salute* Snapshot 2.5TG* Spike-Treflan* Team* Treflan Tri-4 Trific Trilin Tri-Scept*

*Formulated mixture with additional active ingredient(s).
[a]Private label product: toxicity information identical to that for Lasso 4EC.
[b]Private label product: toxicity information identical to that for Basagran.
[c]Private label product: toxicity information similar to that for Roundup (may or may not contain a surfactant).

20 Environmental Toxicities and Properties of Common Herbicides

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Pesticide hazards include the possibility of adverse effects on nontarget organisms. Adverse effects can result from drift, surface runoff, or direct contact with pesticide compounds. The risks to humans, wildlife, or endangered or desirable plant species should be considered prior to a pesticide application. Chapter 18, titled "The Toxicity of Herbicides," is a reference for human toxicity and exposure whereas the present chapter is primarily concerned with exposure of fish and wildlife.

The risks associated with pesticide use should be considered in light of species tolerance and amount of exposure. The amount of exposure may be mitigated by such factors as the size of the area treated, pesticide placement and potential movement, time and rate of application, and half-life of the compound. The information in this chapter and the data in Table 1 are provided as a guide for determining the potential environmental risks of pesticide application. The information in the table is taken from studies conducted by pesticide manufacturers to fulfill requirements for pesticide registration. Because many of these studies were completed prior to the implementation of current standards some data may be missing, incomplete, or reported in nonstandard units.

How to Use the Table

The LC_{50} or lethal concentration of a pesticide is that concentration of a pesticide which will kill 50 percent of test animals. The LC_{50} values of various herbicides for fish are shown in Table 1. For fish, the test consists of treating tank water with pesticide for a short period, typically 96 hours, although treatment periods of 8 hours may be used for particularly toxic pesticides. The LD_{50} is the dosage which proves lethal to 50 percent of test animals when administered through oral routes, usually in food or water. For mallard ducks, 5- to 8-day feeding trials are conducted. The LD_{50} values for ducks refer either to pesticide-treated water (usually reported as parts per million [ppm]) or pesticide-treated food (usually reported in milligrams of chemical per kilogram of body weight [mg/kg]). When interpreting the data from these studies, note that compounds with very small LC_{50}/LD_{50} values have very high toxicities (a small amount may be very toxic). A concentration of 1 ppm is equivalent to 2.7 pounds of pesticide in 1 acre-foot of water. Herbicides with an LD_{50}/LC_{50} value that is between 100 and 2,000 ppm are considered to be of moderate toxicity. Herbicides with an LD_{50}/LC_{50} greater than 2,000 ppm are of low toxicity and those with values less than 100 are considered highly toxic. Some compounds were reported in the literature as either low, moderate, toxic, or very toxic, without numerical data.

The level of species susceptibility to a pesticide may vary due to other stresses an organism may be undergoing, avoidance of the pesticide where possible, and factors such as age and sex. The susceptibility of other species not listed in the table may vary from quoted figures by a factor of 100 or more. In areas where a potential hazard to fish and wildlife exists we recommend the following: (1) select a herbicide with the lowest possible toxicity that is effective for controlling the targeted weeds; (2) limit the size of the treated area as much as possible, for example, by banding or spot treating; (3) make the application at the minimum effective rate; and (4) time the application to occur when the potential for surface water runoff is minimal. Crop management measures which reduce runoff, such as reduced tillage, may reduce herbicide loss, although the mobility of some herbicides can be reduced by lightly incorporating them into the soil surface.

The half-life of the compound in the soil, the surface water, and the air can affect the hazard potential. Variability of this factor is also great and is dependent

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The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

on environmental conditions of light, temperature, and moisture. For a more complete treatment of this topic see Chapter 21, "Factors Affecting Herbicide Persistence."

For the trade names corresponding to the active ingredients listed, see Chapter 19, "Herbicide Formulations and Toxicities." Data from the following table have been extracted from the *Herbicide Handbook* Sixth Edition, 1989, published by the Weed Science Society of America, and from "Extoxnet," a compilation of data by the Cooperative Extension Offices of Oregon State University, Cornell University, the University of California, and Michigan State University.

Table 1. Toxicity and Half-Life of Various Herbicides

Herbicide	Toxicity to			Rate of breakdown or half-life in		
	Bluegill	Rainbow trout	Mallard duck	Soil	Air	Water
	- - - - -*LC_{50}, ppm*- - - - -		*LD_{50}**	- - - - - - - -*days*- - - - - - - - -		
Acifluorfen						
Blazer	62	17	5,620 mg/kg	59	4	2
Tackle	31	54	4,187 mg/kg	59	4	2
Alachlor	6.4	4.2	5,000	42-70	Slow	...
Ametryn	4.1	8.8	23,000	100-180	Slow	...
Amitrole	Not toxic	Not toxic	Not toxic	14-28	Slow	200
Asulam	>3,000	>5,000	4,000	5-15	4	3-9
Atrazine	>24	4.5	19,650	100-180	Slow	...
Barban	1.18	0.614	>10,000	14	...	...
Benefin	...	...	5,000 mg/kg	50-120	Mod	...
Bensulide	...	0.72	...	120	Slow	...
Bentazon	616	190	2,000 mg/kg	14	V. slow	<24 hrs
Bromacil	71	75	>10,000	150	V. slow	...
Bromoxynil	0.10	0.17	200 mg/kg	>100	...	...
Butylate	6.9	7.2	>40,000[a]	10-20	...	...
Cacodylic acid	1,000	...	...	...	V. slow	...
Chlorimuron	...	...	...	21-42	Slow	...
Chlorsulfuron	>250	>250	>5,000	28-42	Slow	...
Clethodim	>100	67	>6,000	2	2	...
Clomazone	34	19	>5,620	28-84	V. slow	...
Clopyralid	125	103	>4,640	12-70	V. slow	...
Copper chelate	1.2	0.2	>1,000	N/A	V. slow	...
Cyanazine	Low	Low	Low	12-25	Slow	...
Cycloate	...	5.6	>56,000[a]	28-42	...	...
2,4-D[b]	>110	64	>1,000 mg/kg	7-28	Slow	7-14
2,4-DB	4	>1,000	7-28	Slow	...	...
DCPA	>320	Not toxic	>5,000	60-100	V. slow	...
Dicamba	>1,000	>1,000	>4,600	14-42	Slow	Slow
Dichlobenil	10	...	...	60-180	V. slow	...
Dichlormid	...	...	...	7-8	V. slow	...
Diclofop methyl	...	1.38	>20,000	10-30	Fast	...
Diquat	...	12.3	564 mg/kg	N/A	Fast	<2
Diuron	7.4	4.3	>5,000	120-240	Mod	Slow
Endothall	...	...	...	...	V. slow	...
EPTC	27	21	20,000[a]	7-14	...	...
Ethalfluralin	0.03	0.04	>5,000 mg/kg	42-56	Mod	...
Fenoxyprop	3.3	3.4	Not toxic	5-14	Slow	
Fluazifop	...	1.4	>17,000 mg/kg	28-56	V. slow	
Fluridone	14.3	11.7	>5,000 mg/kg	Mod	...	
Fomesafen	6,030	680	>5,000 mg/kg	120-240	Fast	
Fosamine	670	1,000	>10,000 mg/kg	10		
Glufosinate	...	>320	>2,000 mg/kg	7		

Table 1. Toxicity and Half-Life of Various Herbicides (cont.)

Herbicide	Toxicity to			Rate of breakdown or half-life in		
	Bluegill	Rainbow trout	Mallard duck	Soil	Air	Water
	-----LC50, ppm-----		*LD50**	*--------days--------*		
Glyphosate						
Roundup	4	110	>4,640	3	V. slow	...
Rodeo	1,000	>1,000	>4,640	3	V. slow	...
Haloxyfop	0.2	0.4	>2,150	10-50	V. slow	...
Hexazinone	>370	>320	>10,000	60-120	Mod	Mod
Imazapyr	>100	>100	>5,000 mg/kg	90-180	Mod	2
Imazaquin	V. low	V. low	V. low	90-180	...	...
Imazethapyr	420	340	>5,000	90-180	...	...
Lactofen	1.1	1.1	...	14-21	Mod	Mod
Linuron	16	16	3,083	60-120	V. slow	Mod
MCPA	>10	...	...	10-180	V. slow	...
MCPP	...	...	...	7-21	V. slow	...
Mefluidide	1,600	>1,200	>1,000	2	Slow	Fast
Metolachlor	10	2	>10,000	25-50	8	V. slow
Metribuzin	>100	>100	>100 mg/kg	30-60	V. slow	...
Napropamide	...	...	...	56-100	4	...
Naptalam	...	...	...	21-42	V. slow	...
Norflurazon	...	...	...	48-180	Mod	...
Oryzalin	2.9	3.6	>5,000 mg/kg	60-180	Mod	...
Oxyfluorfen	V. toxic	V. toxic	V. toxic	30-40	Fast	Fast
Paraquat	V. toxic	V. toxic	V. toxic	nd[c]	Mod	Mod
Pendimethalin	...	...	...	30-60	Slow	...
Picloram	...	4	>5,000 mg/kg	70-100	Mod	...
Prometon	>32	20	4,572	100-200	Mod	...
Prometryn	10	2.5	39,000	30-90	Mod	Slow
Pronamide	100	72	>20,000 mg/kg	60-270	Slow	...
Propachlor	1.6	0.42	>5,000	30-42	V. slow	...
Pyridate	Low	Low	Low	...	Fast	...
Quizalofop	0.5-3.0	0.9	>2,000 mg/kg	7-21	Mod	...
Sethoxydim	...	...	...	4-10	Mod	Fast
Simazine	2.8	16	51,000	30-90	Mod	...
Sodium borate	Low	Low	Low	>365	V. slow	...
Sodium chlorate	V. toxic	V. toxic	...	...	...	...
Sulfometuron	>12.5	>12.5	>5,000	...	...	...
Tebuthiuron	112	144	>2,000 mg/kg	360-500	Slow	...
Terbacil	86[d]	...	>56,000	180	...	...
Thifensulfuron	>100	>100	>5,600	7-21	...	...
Triallate	1.3	1.2	>5,000	48-56	V. slow	...
Triclopyr						
Garlon 3A	891	552	>10,000	46	Fast	V. fast
Garlon 4L	0.9	0.7	>10,000	...	...	...
Trifluralin	Toxic	Toxic	>5,000 mg/kg	60-90	Mod	...

Table 1. Toxicity and Half-Life of Various Herbicides (cont.)

Herbicide	Toxicity to			Rate of breakdown or half-life in		
	Bluegill	Rainbow trout	Mallard duck	Soil	Air	Water
	- - - - -LC_{50}, ppm- - - - -		*LD_{50}**	*- - - - - - - -days- - - - - - - -*		
Safeners in certain herbicide formulations:						
Concept II	12	7.1	>2,000	...	...	...
Dietholate	...	...	...	14-28	...	...
R-29148	...	...	...	...	V. slow	...

[a]Quail were used as test animals.
[b]Some formulations are particularly toxic to fish.
[c]Bound too tightly to soil for determination.
[d]Pumpkinseed sunfish were used as test animals.
*Reported as ppm unless otherwise noted.

21 Factors Affecting Herbicide Persistence

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Herbicides are applied to the soil in hopes of obtaining season-long weed control. It is desirable for the chemicals to control weeds during the season of application, but they should not remain to affect subsequent crop growth. The length of time that a herbicide remains active in the soil is called "soil persistence" or "soil residual life." Anything that affects the disappearance or breakdown of herbicides will affect persistence. Many factors determine the length of time herbicides persist. Most factors fall into three categories: soil factors, climatic conditions, and herbicidal properties. These categories strongly interact with one another.

Herbicides vary in their potential to persist in the soil. Some herbicide families that have persistent members include the triazines, uracils, phenylureas, sulfonylureas, dinitroanilines, pigment inhibitors, imidazolinones, and certain plant growth regulators. Table 1 lists several common herbicides in these groups. Table 2 lists the soil persistence of some common herbicides.

Soil Factors

The soil factors affecting herbicide persistence fit into three categories: physical, chemical, and microbial. Soil composition is a physical factor that measures the relative amounts of sand, silt, and clay (the soil texture) and the organic-matter content of the soil. Chemical properties of the soil include pH, cation exchange capacity (CEC), and nutrient status. The microbial aspects of the soil environment include the type and abundance of soil microorganisms present.

Soil composition affects phytotoxicity and persistence through adsorption, leaching, and volatilization. Generally, soils high in clay or organic matter or both have a greater potential for carry-over because of increased adsorption to soil colloids with a corresponding decrease in leaching and loss through volatilization. This "tie-up" results in decreased initial plant uptake and herbicidal activity. Therefore, more herbicide is held in reserve to be released later, potentially injuring susceptible future crops.

Some herbicides, principally the triazines (atrazine and simazine), are particularly affected by soil pH, an important part of the soil chemical makeup. Lesser amounts of these herbicides are adsorbed or held to soil colloids at higher soil pH, so they remain in the soil solution. Herbicides in the soil solution are available for plant uptake. Chemical breakdown and microbial breakdown, two major herbicide degradation processes, are often slower in higher pH soils. So although decreased adsorption of triazine herbicides occurs in higher pH soils, there is also less breakdown activity. Therefore, these herbicides are more available for plant uptake for a longer period of time on higher pH soils. Certain members of the sulfonylurea group (chlorsulfuron and chlorimuron) can also persist in higher pH soils because of decreased rates of chemical breakdown. Low pH affects the persistence of the imidazolinones (imazaquin and imazethapyr). Soil pH has little effect on the persistence of other herbicides.

Research shows that various nutrients and cations in the soil affect both herbicide activity and degradation. The CEC, principally a function of clay type and organic-matter content, is directly involved in herbicide adsorption. Some herbicides are more available in the presence of certain cations, whereas others may be tied up and therefore unavailable. The literature indicates that there is much variation in the effect that cations and nutrients can have on herbicide activity and breakdown, depending on soil composition, nutrient type and concentration, and the chemistry of the herbicide. Soil microorganisms are partially responsible for the breakdown of many herbicides. The types of microorganisms and their relative amounts will determine how quickly decomposition occurs. Soil microbes require certain environmental conditions for optimum growth and utilization of any pesticide. Factors that affect microbial activity are temperature, pH, oxygen, and mineral nutrient supply. Usually, a

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Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

Table 1. Herbicide Families with Their Persistent Members

S-triazines	Phenylureas	Sulfonylureas
atrazine (AAtrex, Atrazine, Griffex)	diuron (Karmex)	chlorimuron (Classic)
hexazinone (Velpar)	fluometuron (Cotoran)	chlorsulfuron (Glean)
simazine (Princep)		nicosulfuron (Accent)
	Uracils	primisulfuron (Beacon)
Dinitroanilines	bromacil (Hyvar-X)	sulfometuron (Oust)
benefin (Balan)	terbacil (Sinbar)	**Plant growth regulators**
ethalfluralin (Sonalan)	**Imidazolinones**	clopyralid (Stinger)
oryzalin (Surflan)	imazapyr (Arsenal)	picloram (Tordon)
pendimethalin (Prowl)	imazaquin (Scepter)	
trifluralin (Treflan, Tri-4, Trific, Trilin)	imazethapyr (Pursuit)	
Others		
bensulide (Prefar, Betasan)		
clomazone (Command)		
fluridone (Brake, Sonar)		
tebuthiuron (Spike)		

warm, well-aerated, fertile soil with a medium soil pH is most favorable for microorganisms and hence herbicide breakdown.

Climatic Factors

The climatic variables involved in herbicide breakdown are moisture, temperature, and sunlight. Herbicide degradation rates generally increase with increased temperature and soil moisture because both chemical and microbial decomposition rates increase under higher temperature and moisture. Cool, dry conditions slow down herbicide degradation causing greater carryover potential. If winter and spring conditions are wet and mild, the likelihood of herbicides to persist is less.

Sunlight is also an important factor in herbicide degradation. Photodecomposition, or decomposition by light, has been reported for many herbicides. The dinitroanilines (trifluralin, pendimethalin, and ethalfluralin) are sensitive to light degradation. They may be lost when surface applied if they remain for an extended time without rainfall. Therefore, degradation would be accelerated on very sunny days. This sensitivity to light and loss by volatility are primary reasons for soil incorporation.

Herbicidal Properties

Finally, the chemical properties of a herbicide affect its persistence. Important factors include water solubility, vapor pressure, and susceptibility to chemical and microbial alteration or degradation. The water solubility of a herbicide helps to determine its leaching potential. Leaching occurs when a herbicide is dissolved in water and moves down through the soil profile. Herbicides that readily leach may be carried away or carried to susceptible plant rooting zones. Herbicide leaching is determined not only by its water solubility, but also by its ability to adsorb to soil particles. Additionally, soil texture and available soil water affect herbicide leaching. Herbicides that are low in water solubility, strongly adsorbed to soil colloids, and exist in dry soils are less likely to leach and have a greater potential to persist.

The vapor pressure of a herbicide determines its volatility. Volatility is the process whereby a herbicide changes from a liquid or solid to a gas. Volatility increases with temperature. Volatile herbicides such asthe thiocarbamates (EPTC, butylate) must be incorporated immediately to avoid gaseous losses. These herbicides are less likely to persist than herbicides with a low vapor pressure.

Herbicides may be rapidly decomposed by microorganisms in the soil if the right kind and number of microorganisms are present and if soil conditions are favorable for their growth. However, herbicides vary greatly in their susceptibility to microbial decomposition. For example, microbial decomposition of 2,4-D occurs very quickly in the soil, whereas atrazine

Table 2. Soil Persistence of Some Common Herbicides Applied at Labeled Illinois Use Rates

1 month	1 to 3 months	3 to 12 months	More than 12 months
2,4-D	acifluorfen (Blazer)	atrazine	bromacil (Hyvar)
glyphosate (Roundup)	alachlor (Lasso)	benefin (Balan)	chlorsulfuron (Glean)
MCPA	ametryn (Evik)	bensulide (Prefar, Betasan)	picloram (Tordon)
paraquat (Gramoxone)	bentazon (Basagran)	bromoxynil (Buctril)	prometon (Pramitol)
	butylate (Sutan)	chlorimuron (Classic)	sulfometuron (Oust)
	cyanazine (Bladex)	diuron (Karmex)	tebuthiuron (Spike)
	DCPA (Dacthal)	ethalfluralin (Sonalan)	
	EPTC (Eptam, Eradicane)	fomesafen (Reflex)	
	linuron (Lorox, Linex)	fluridone (Brake, Sonar)	
	metolachlor (Dual)	clomazone (Command)	
	metribuzin (Sencor, Lexone)	hexazinone (Velpar)	
	naptalam (Alanap)	imazaquin (Scepter)	
	propachlor (Ramrod)	imazethapyr (Pursuit)	
	siduron (Tupersan)	oryzalin (Surflan)	
		pendimethalin (Prowl)	
		pronamid (Kerb)	
		simazine (Princep)	
		terbacil (Sinbar)	
		trifluralin (Treflan)	

degradation is slow.

Chemical decomposition is dependent not only on the chemistry of the herbicide (how susceptible it is to chemical breakdown), but also on soil and climatic factors. Chemical breakdown of a herbicide involves reactions such as hydrolysis, oxidation, and reduction. The occurrence of these reactions and the rates at which they take place will vary with soil type and climatic conditions. These reactions along with microbial degradation are important processes in the decomposition of herbicides.

Avoiding Herbicide Persistence in Subsequent Crops

There are several ways to avoid herbicide carryover problems. First, always apply the correct rate of any pesticide for your specific soil type and weed problem. This means applying the lowest rate of the chemical consistent with obtaining the desired effect. In order to accomplish this goal, accurate acreage determination, accurate chemical measurement, proper sprayer calibration, and uniform application are essential. Always read the label before applying any herbicide.

The method and time of application can be important in avoiding herbicide carryover. Some herbicides must be incorporated. However, if herbicides have the potential to persist longer than desired, those applied preplant incorporated will more likely remain longer than those surface applied without incorporation. Incorporating the herbicide makes it less susceptible to loss by volatilization and photodecomposition. In addition, an incorporated herbicide is immediately exposed to charged soil particles and possibly tied up through adsorption. Decreased environmental losses (volatilization and photodecomposition) and increased adsorption both favor herbicide carryover. Banded herbicide applications can reduce carryover potential because less total herbicide is applied in a band than in a broadcast application. Postemergence foliar and later soil applications have a greater potential than earlier application for being present in next year's crop.

The amount of tillage will affect herbicide persistence. Tillage encourages herbicide decomposition indirectly through increased microbial and chemical breakdown. Minimum-till and no-till, which leave crop residue on the soil surface, also tend to leave a greater concentration of herbicide near the surface zone. Persistent herbicides present in this concentrated zone may affect susceptible crops. In addition, higher rates of herbicides are often used in reduced tillage systems to maximize weed control and adjust for greater amounts of crop residues. If a herbicide carryover problem already exists, some tillage to dilute the chemical may help.

Herbicide combinations may reduce the risk of carryover problems. By tank-mixing two or more herbicides, we might reduce application rates of those products that potentially cause problems and at the same time broaden our weed control spectrum.

Herbicides may interact with one another or with other pesticides and enhance crop injury when they are applied in the same or in consecutive years. For example, a soybean crop may tolerate a certain level of atrazine carryover. However, if another photosynthetic inhibitor such as metribuzin is applied to soybeans after atrazine-treated corn, injury is more likely.

Plants absorb herbicides from the soil in which they are growing. Persistence may be less if the herbicide is metabolized or broken down by the plant or if the plant containing the absorbed herbicide is harvested and removed from the field. Plant extraction of the herbicide from the soil may not be an important factor under most situations, but it has been used in some situations to help remove persistent herbicides from treated soils.

Finally, the selection of a tolerant rotational crop or variety will help minimize carryover problems. Quite often, economics will dictate crop rotation; however, there are varietal differences that might affect the likelihood of serious crop injury. For example, some soybean varieties are more sensitive to the triazine herbicides than others and should not be used if the potential for triazine injury exists. Also, as a general rule, smaller seeded crops and varieties have a greater potential for injury from persistent herbicides than do larger seeded species.

If herbicide carryover is suspected, a soil chemical test or biological assay can help determine if harmful levels of herbicide residue are present. Chemical analysis can be expensive, so a bioassay may be more feasible. Either can help you to determine if herbicide residues exist and if a tolerant crop or variety should be planted into a problem area. (See Chapter 22, "Testing for Herbicide Residues," in this handbook.)

Many variables interact in predicting herbicide persistence. Factors involved in the degradation of herbicides include many soil, climatic, and herbicidal properties. The potential for herbicide carryover problems can be reduced by using the appropriate rates and the accurate timing of proper application methods. The use of selective tillage, herbicide combinations, and tolerant crops and varieties can also help reduce the risk of crop injury.

22 Testing for Herbicide Residues

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Herbicides vary in their potential to persist in soil. Those herbicides that can persist to the next season may injure subsequent crops and need to be monitored closely. Two methods used to determine if harmful herbicide residues might exist are a soil chemical test done at a laboratory and a bioassay done either in the suspect field or in a warm, sunny indoor location, such as a greenhouse. These tests help predict potential herbicide residue problems so that the grower can make better decisions about crop rotation, herbicide selection, planting date, and other cultural practices.

Soil Collection and Preparation

With the lab analysis or indoor bioassay, proper sampling of the soil is the first step. The soil sampling procedures for submitting a soil for laboratory analysis and for conducting an indoor bioassay are similar. These guidelines should be followed.

1. Collect representative soil samples from the suspect field. Samples should be collected in early to midspring or prior to planting. Take samples from several locations in the field. For the bioassay or laboratory analysis, take 15 to 20 soil cores and combine them to make a composite sample. This sample should represent no more than 15 to 20 acres. Enough areas must be sampled to avoid missing locations with high herbicide residue content. Take separate samples from areas where excessive residues are suspected, such as sprayer turnaround points and end rows. Do not mix these samples with the others. Sample the soil to a 6-inch depth and divide the samples into 0- to 3-inch and 3- to 6-inch sections for greater accuracy. Be sure to mark on the bags the depths from which the samples came. Approximately 8 pounds of soil (4 quarts) are needed for each bioassay and 2 pounds of soil (about 1 quart) for each laboratory analysis.

2. Sample an area that is not suspect for use as a "check" soil. This soil may be taken from a nearby fence row, garden, or other untreated area. Keep this sample separate from others. Many laboratories require a check.

3. Submit the samples to the laboratory as soon as possible after sampling. If bioassays are to be performed, they should be run on the soil samples as soon as possible after they have been obtained from the field. If samples cannot be assayed immediately, then store the soil in a refrigerator or freezer that is not used for food. If samples are stored in a warm environment, herbicide residue may decrease with time.

Bioassay

The bioassay can help predict potential crop injury. These tests are inexpensive and can be done with a few simple supplies. A bioassay does not measure the amount of herbicide residue present in the soil, but it may indicate whether enough residue is present to harm a sensitive crop.

Field Bioassay

A field bioassay is conducted by planting one or more strips of a sensitive species in a suspect field. This procedure can be done in the fall or spring, but it is more accurate if performed closer to the planting of the intended crop. Before planting the desired crop, allow the test plants to grow and develop symptoms of injury of any herbicide residues. The strips should be planted in several locations if possible, and include an area that is most suspect and an area that can serve as a check. Choose an appropriate species for the bioassay, such as one of the more sensitive ones listed in this paper. Include several species of differing sensitivity for greater accuracy.

Indoor Bioassay

The procedure for conducting an indoor bioassay

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will vary depending on what herbicide residue is of concern. For the indoor bioassay, the procedures for soil collection and preparation, however, are the same.

1. For the indoor bioassay, take the samples and allow them to air dry if needed until they can be worked readily. Do not overdry the samples. If the soil is cloddy, crush the clods into small pieces (the size of a pea or smaller). If the soil contains a high amount of clay, the addition of coarse sand (50 percent by volume) will improve its physical condition. If sand is added, thoroughly mix it with the soil.

2. Tin cans, milk cartons, or cottage cheese containers are appropriate containers in which a bioassay can be conducted. Punch holes in the bottom of the containers to allow water drainage. Fill two or more containers (a set) with soil from each sample. Additional containers will increase the accuracy of the test. Place the soil samples obtained from the 0- to 3-inch depth in one set of containers, and in another set, place the soil obtained from the 3- to 6-inch depth. Follow this procedure for the composite sample and the sample taken from areas where excessive residues are expected. In addition, fill a final set of containers with the check soil.

Testing for Specific Herbicide Groups

Triazine Residues

For suspected carryover from triazine herbicides such as atrazine and Princep (simazine), an oat plant bioassay works best. Place about 15 oat seeds in each container of soil and cover the seeds with approximately 1 inch of soil. Wet the soil with water but do not saturate it.

Place the containers in a warm location (70° to 75°F) where they will receive ample light. Sunlight is essential for the development of the plant as well as for inducing symptoms of triazine injury. The container should be watered when necessary.

Injury symptoms should become apparent within 10 to 14 days after planting. Triazine injury is characterized by chlorosis (yellowing) followed by necrosis (browning) of the leaf tissue. Injury symptoms will start at the leaf tip and develop toward the base.Therefore, it is essential that a comparison with the plants in the check soil be made.

If injury appears on the oats, then enough herbicide residue may be present to injure a susceptible crop. Planting a more tolerant crop is suggested. In general, the order of susceptibility to triazine herbicides is:

Triazine: Ryegrass > Alfalfa > Oats > Wheat > Soybean > Sorghum > Corn

DNA Residues

If residues from dinitroaniline (DNA) herbicides, such as Treflan (trifluralin) or Prowl (pendimethalin) are suspected, a different assay technique is used. A sorghum or corn root bioassay is relatively quick and easy to perform.

Wrap sorghum or corn seed in a moist paper towel and store it at room temperature for 2 to 3 days. This procedure allows the seed to imbibe water and germinate. Once the seed has germinated, carefully place three to five seeds into containers with the suspect soil and check soil. Cover the seeds with soil to a depth of approximately 1 inch, and leave them for 10 to 14 days, depending on the air temperature. Water the plants as needed but do not saturate the soil.

At the end of the 7- to 14-day period, carefully remove the plants and observe the root formation. DNA herbicides inhibit root development. Symptoms include stunted plants, stubbed roots, inhibited root-hair development, thickened hypocotyls on broadleaf species, and leaves that fail to unroll. If the plants in the suspect soil display any of these symptoms in comparison to the check plants, then DNA residues may be present at concentrations high enough to injure susceptible crops. In general, the order of susceptibility to DNA herbicides is:

DNA: Annual Rye > Oats > Sorghum > Corn > Wheat > Alfalfa > Soybean

Imazaquin, Imazethapyr, or Chlorimuron Residues

Imazaquin, the active ingredient in Scepter and a component of Squadron and Tri-Scept; imazethapyr, the active ingredient in Pursuit and a component of Pursuit Plus; and chlorimuron, the active ingredient in Classic and a component of Preview, Canopy, and Lorox Plus, have the same mode of action in sensitive plants. These herbicides affect root and shoot growth and development. Symptoms of plant injury include inhibited root development, stunted plants, and interveinal chlorosis or leaf striping. Therefore, a sorghum or corn root bioassay performed according to the procedure outlined for suspected DNA residue is appropriate. Corn is more sensitive to imazaquin, and sorghum is more sensitive to imazethapyr and chlorimuron. In addition to root observations, look for stunted shoot growth and interveinal chlorosis or yellowing. Bioassay plants should be grown for 14 to 21 days. The order of crop susceptibility to imazaquin, imazethapyr, and chlorimuron is as follows:

Imazaquin: Rape > Alfalfa = Corn = Sunflower > Sorghum > Oats > Wheat > Soybean

Imazethapyr: Rape > Sorghum > Sunflower > Oats > Wheat > Alfalfa = Corn > Soybean

Chlorimuron: Rape > Alfalfa > Sunflower > Sorghum > Corn > Oats > Wheat > Soybean

Command (Clomazone) Residues

Command and Commence inhibit the production of photosynthetic pigments in susceptible plants and, therefore, cause plants to emerge lacking green color, that is, white or albino. Lower levels of Command residue may appear as a chlorosis or mild bleaching of the plants. Oats or wheat can be used to detect Command residues using the same procedure as outlined above for detecting triazine residues. Bioassay plants should be grown for 10 days to 2 weeks. Susceptible plants that are exposed to significant levels of Command residues will be white, while untreated or tolerant plants will be green. Keep in mind that oats and wheat are usually more susceptible than corn to injury from Command. The order of susceptibility to Command residues is as follows:

Command: Oats = Wheat = Alfalfa > Sunflower = Sorghum = Corn > Soybean

Other Residues

Bioassays can be made for other herbicides using similar techniques. If the mode of action of a specific herbicide is known, then we can develop a procedure for detecting the herbicide. For example, if the herbicide is a root meristematic inhibitor, that is, if it stops cell division in the roots, then a root bioassay is the appropriate test. If the herbicide inhibits photosynthesis, then injury symptoms will first appear in the leaves. Choose a species that is moderately susceptible to the suspected herbicide, and always include a check soil. Wheat and oats are very good indicator plants for many herbicides but may be more sensitive than the desired crop. Include several species in the bioassay to give a better range of susceptibility. The desired crop is a good bioassay plant to include.

Laboratory Analysis

Laboratory analysis involves extracting the herbicide from the soil with the use of specialized equipment to detect very small amounts of herbicide. The amount of herbicide is expressed in parts of herbicide per million parts of soil (ppm). Parts of herbicide per million parts of soil can be transposed into pounds of herbicide per acre if we assume that an acre (A) of soil weighs 1,000,000 pounds in the top 3 inches and 2,000,000 pounds in the top 6 inches.

Thus, for a soil sample taken to a 6-inch depth, 1 ppm = 2 lb/A of residue.

For a soil sample taken to a 3-inch depth, 1 ppm = 1 lb/A of residue.

So a lab reporting 0.2 ppm atrazine means that there is 0.2 pound of atrazine per acre if the samples were taken to a 3-inch soil depth, and 0.4 pound per acre if taken to a 6-inch soil depth.

The location and concentration of the chemical will depend on what herbicide is used, the soil type, whether the ground was tilled, and the amount of rainfall since application. In most medium-textured soils (silt loams, silty clay loams, sandy clay loams), the herbicide remains primarily in the top 3 inches unless there was excessive rainfall, the ground was plowed, or the herbicide was deeply incorporated. If the soil has a high sand content (coarse texture), then herbicide leaching may be greater. Movement of the herbicide out of the surface soil zone by tillage or by rainfall decreases the likelihood of crop injury. The risk of injury is increased when the herbicide residue is concentrated in the top 3 inches rather than distributed throughout the 6-inch soil depth. Therefore, it is best to sample the 0- to 3-inch and 3- to 6-inch sections separately.

Whether we use parts per million or pounds of active ingredient of herbicide, it is difficult to translate these units of measure into potential crop injury. Many variables affect crop susceptibility or tolerance, including soil type, crop sensitivity, and environmental conditions after planting. Crop injury is more likely on more coarsely textured soils or under cool, wet weather conditions. Additionally, high soil pH increases the potential of triazine or chlorimuron injury.

General guidelines are provided in Table 1, although the reader is cautioned that crop injury may still occur below these levels.

Laboratories may differ in available tests and in the price of the analysis. The cost can range from $20 to $200 per sample or herbicide analysis. Most laboratories can analyze a sample and have the results in 5 to 7 days. Contact your local Extension office for more information on laboratory selection.

Correcting for Herbicide Residues

If the lab test or bioassay indicates that a potential herbicide residue problem exists, several steps can be taken.

1. First select a tolerant crop or variety. This selection will depend on what herbicide is of concern. Check current herbicide labels for more information on crop tolerance.

2. Till to help dilute the herbicide in a problem field.

Table 1. General Guidelines for Interpreting Laboratory Analysis

Herbicide	Safe level* Parts per billion	Safe level* Parts per million	Crop
Triazine	150–250	0.150–0.250	Soybean
	< 100	< 0.100	Alfalfa, oats, wheat
Dinitroaniline	100–200	0.100–0.200	Corn
	200–300	0.200–0.300	Wheat
Clomazone	50–200	0.050–0.200	Corn
	15–100	0.015–0.100	Wheat, alfalfa
Imazaquin	2–10	0.002–0.010	Corn
	10–30	0.010–0.030	Wheat
Imazethapyr	10–30	0.010–0.030	Corn
	4–15	0.004–0.015	Sorghum
Chlorimuron	1–2	0.001–0.002	Corn
	2–5	0.002–0.005	Wheat

*Due to differences in herbicide availability from the soil, "safe" values for herbicide residues differ according to soil type. Low range values are for coarsely textured soils with low levels of organic matter; higher range values are for finely textured soils with higher levels of organic matter. (1 ppm = 1,000 ppb)

3. Plant last the field that concerns you. Delaying the planting allows more time for the herbicide to break down.

4. If the triazine herbicides or chlorimuron (Classic, Canopy, Gemini, Preview, or Lorox Plus) are suspect, be sure to check the soil pH and adjust your management practices accordingly.

5. If imazaquin or imazethapyr are suspect, check for low soil pH (< 5.5). Liming would both benefit crop growth and minimize carryover of these herbicides.

In summary, a bioassay or laboratory test is not 100 percent accurate in predicting herbicide residue problems. Crop response to herbicide residue depends on a number of factors, including species and variety, soil type, and environmental conditions after planting. Therefore, predicting crop injury is often difficult. However, using a soil chemical test or biological assay can help in deciding whether a potential problem exists and in choosing the appropriate crop or variety.

23

Suggestions for Minimizing Bee, Fish, and Wildlife Losses from Pesticides

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It may be impossible to use pesticides without endangering some nontarget species. However, through prudent use, pesticide hazards to fish and wildlife can be substantially reduced. Here are some precautions to follow:

- Apply pesticides according to the instructions given by the manufacturer and the Cooperative Extension Service.
- If more than one pesticide is available to control a specific pest, use the pesticide least toxic to nontarget organisms.
- Avoid drift.
- Follow instructions for disposing of pesticide containers.
- In wildlife and aquatic areas, use ground equipment so that pesticides can be confined to specific target areas.
- Make sure that pesticide-treated seed is not readily available to birds or mammals.
- For application to water, use only those pesticides registered by the federal Environmental Protection Agency (EPA) for aquatic use (Rule 203h, Water Pollution Regulations, as amended).
- If a pesticide is extremely toxic to fishes, avoid applying it in the immediate watershed, including ditches and channels that drain into bodies of water.
- Wash application equipment properly, and do not permit wash water to contaminate any body of water.

Pesticides and Their Effects on Wildlife

There is still much to learn about the overall effects of any pesticide on any population of vertebrate animals in the wild. Certain general facts have been established, however. Considerable data are available on the acute toxicity of various compounds to a variety of species in captivity. Also, there are a limited number of studies of population recovery rates after one or more applications of a pesticide to an area. Some pesticides may cause high mortality in populations of wild vertebrates both directly and indirectly through the food chain. It has been shown that persistent chemicals, such as the chlorinated hydrocarbons, are concentrated from the bottom to the top of the food chain. Animals at the top of the food chain often accumulate heavy dosages of the toxin, which can cause whole populations to lose their reproductive capacity. Accumulations of organochloro insecticides through the food chain, for example, may have reduced the reproductive capacity of the bald eagle, duck hawk, and other raptor populations both in Europe and North America. The reproductive capacity of certain species of fishes and fish-eating birds, such as loons, cormorants, and pelicans, may have been reduced as well.

Although this discussion refers to all wild vertebrates, most of the remarks and examples refer to birds. Because of their migratory and highly mobile nature, birds are more susceptible to poisoning in large numbers from a single application of pesticide.

The simpler the habitat, the fewer organisms it supports, in terms of the variety or diversity of organisms. Conversely, the more complex the habitat, the greater the number and variety of organisms. For example, in summer, bare plowed ground usually

The information in this chapter is provided for educational purposes only. Product trade names have been used for clarity, but reference to trade names does not imply endorsement by the University of Illinois; discrimination is not intended against any product. The reader is urged to exercise caution in making purchases or evaluating product information.

Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

supports only about three to five native species of birds with only about one bird for every 2 acres. At the other extreme is a forest, which supports about 80 to 85 nesting species of birds with about five to eight birds per acre.

Of the agricultural habitats in Illinois, corn and soybean fields have the lowest bird populations, essentially the same as plowed bare ground; wheat fields support only slightly higher numbers; and oat fields have conspicuously higher bird populations. Grasslands and hayfields are very rich bird habitats, with 40 to 70 native species in the summer and three to five birds per acre. The shrub borders and hedges at the edges of cultivated fields have some of the densest populations of birds of any Illinois habitat. Marshlands also have high populations and many species. In Illinois, the prairie-grassland and marsh-dwelling species are in greatest danger, declining to dangerously low population levels.

Regrettably, the effects of pesticides applied to a field may not stop at the borders of that field. Animals, especially birds, from adjacent fields may pass through a pesticide-treated field or forage at its boundaries. A 1964 study in Illinois indicated that in a single breeding season two successive populations of birds in a hayfield were killed from the effects of one application of 1/4 pound of dieldrin on a nearby wheat field. The hayfield had not been sprayed, but the birds there were dead. A third population of birds that moved into the hayfield within a month of the spray date was unable to produce fertile eggs.

Populations of birds shift greatly from season to season. Between April 15 and June 10, and again between September 1 and November 15, the bird populations in all parts of Illinois reach their greatest numbers. More than 200 species are present in the state, and their numbers are many times greater than the normal breeding populations. Many of these species are insectivorous. After October 1, increasing numbers of waterfowl appear in the wetlands of the state. The songbird populations penetrate every habitat, but they are most abundant where there is some woody vegetation. Populations of songbird migrants in open habitats probably reach their peaks in late March to mid-May and again in October and early November. Fortunately, most of the migrants do not spend time in plowed fields or in corn and bean fields, that is, in bare fields. An exception is the golden plover, thousands of which pass through the state in April and May; these birds regularly feed in bare fields and grasslands and concentrate particularly around rain pools.

In Illinois, bird populations reach their lowest levels in the northern third of the state in the winter (January 1 to March 1). But in the southern third of the state, winter populations are even higher than the summer populations in practically all habitats.

Facts About Pesticides and Fish Mortality

Only pesticides labeled for use in aquatic areas may be applied to water, wetlands (swamps, bogs, marshes, and potholes), lakes, streams, ponds, and ditches. Improper application of chemicals registered for use in aquatic systems can kill fish. For example, Hydrothol 191 is labeled for algae control in lakes and ponds, but fish will be killed by dosages in excess of 0.3 ppm. Fish kills may also occur with these chemicals if there is a spill, or if an improper formulation or an adjuvant toxic to fish is used. Improper vegetation management may cause fish kill due to oxygen depletion either from an overabundance of plants, plant death and decomposition that occur naturally, or from improper pesticide use.

Not all pesticides are dangerous to fish. Some are unstable in water or have low toxicity toward fish. However, many pesticides are toxic to fish. Sensitivity of fish to toxicants varies greatly from species to species, even within the same genus. Any type of pesticide—including insecticides, herbicides fungicides, adjuvants, fumigants, and rodenticides—may kill fish. Table 1 shows comparative fish toxicities of some agricultural insecticides used in Illinois. Similar information for other types of pesticides is not readily available. Always read the environmental hazards in the precautionary statements section of the label. If the product is toxic to fish, use extreme caution to keep it from reaching water bodies.

Residues from pesticides toxic to fish can reach water bodies in a number of ways. Use proper precautions to prevent particle drift from target areas. Prevent runoff from pesticide-treated fields. Consider pesticide chemical characteristics such as persistence, solubility, and adsorption ability. Highly soluble chemicals dissolve readily in water and may enter nearby water resources more quickly. Aerial applications should avoid water bodies. As always, avoid pesticide spills. Do not contaminate water by cleaning equipment or disposing of waste in the water bodies.

Diagnosing the cause of a fish kill is extremely difficult, even for experts. In fish kills due to oxygen depletion, the largest fish typically die first. Disease outbreaks usually kill only one species or species related to it. Insecticide-killed fish will show erratic movement. The young fish die first and are contorted when pulled from the water. Another cause of fish kill

Table 1. Fish Toxicities of Agricultural Insecticides Most Commonly Used in Illinois

Trade name	Common name	Comments
Ambush, Pounce Asana Counter Dyfonate Force Lorsban Thimet	permethrin esfenvalerate terbufos fonofos tefluthrin chlorpyrifos phorate	*Extremely toxic.* Do not use in the vicinity of streams or ponds or where drift or runoff will probably occur.
Cythion Diazinon Furadan Imidan Mocap	malathion diazinon carbofuran phosmet ethoprop	*Highly toxic.* Use great caution if applied in the immediate vicinity of streams and ponds.
Cygon Lannate Larvin Penncap-M Sevin	dimethoate methomyl thiodicarb methyl parathion carbaryl	*Moderately toxic.* Use cautiously around streams and ponds. Avoid direct application of the pesticide to fish-bearing ponds or streams.
Dipel Orthene	*Bacillus thuringiensis* acephate	*Least toxic.* Reasonably safe for use around fish-bearing ponds or streams.

includes runoff of ammonia from feedlots and septic fields during heavy rainfall or spring thaw.

Some Facts About Pesticides and Bees

Bees are highly important as pollinators of apples, pumpkins, clovers, cantaloupes, watermelons, blueberries, cucumbers, squash, and other crops in Illinois. Honey bees visit blooming soybeans in all areas of the state and improve yields of some varieties. The bees also visit sweet corn and field corn tassels when they are shedding pollen. Applicators should consider the bees' presence before applying insecticides during soybean bloom and when corn is pollinating. Highly poisonous to bees of all kinds, some common insecticides may cause serious losses to social bees, such as honey bees and bumble bees, as well as to the less-known solitary bees, such as alkali bees and leaf cutter bees.

Efficient management of pest control programs, and of bees, can do much to reduce the loss of bees through necessary agricultural pest control operations. Relating spraying operations to daily bee activity, insecticide toxicity, plant maturity, and the potential for spray drift will reduce bee losses and may mean the difference between a satisfied producer and one faced with a lawsuit.

The toxicity of insecticides to bees can be drastically modified by abnormal weather conditions. Unusually low temperatures that occur after an application can cause insecticide residues on crops to remain toxic to bees up to 20 times longer than during reasonably warm weather. Also, if abnormally high temperatures occur during late evening or early morning, bees may actively forage on treated crops during these times when bees are usually less active.

Relative Toxicity of Pesticides to Honey Bees

Pesticides differ greatly in their effects on honey bees. The formulation of the pesticide also plays an important role in its toxicity to bees. In general, sprays are safer than dusts, and emulsifiable concentrates are less toxic than wettable powders. Granular materials usually are not hazardous to bees. Microencapsulated formulations of highly toxic materials are extremely hazardous to bees. Penncap-M should not be used on crops visited by bees or in locations where it may contaminate other blooming crops or weeds. Fungicides, acaricides (miticides), herbicides, defoliants, desiccants, nematicides, and blossom thinners are relatively nontoxic.

Pesticides can be placed in three groups in relation to their effects on bees: highly toxic, moderately toxic, and relatively nontoxic.

Highly Toxic Materials

This group includes materials that kill bees on contact during application and for one or more days after treatment. Move bees from the area if highly toxic materials will be used on plants the bees are visiting.

Pesticides

Common name	Trade names
acephate	Orthene
aldicarb	Temik
arsenicals	
azinphos-methyl	Guthion
bifenthrin	Brigade, Capture
	Bioethanomethrin
carbaryl	Sevin
carbofuran	Furadan
carbosulfan	Marshal
chlorpyrifos	Dursban, Lorsban
cyhalothrin	Karate
cypermethrin	Ammo, Cymbush
DDVP, dichlorvos	Vapona
decamethrin	Decis
diazinon	Spectracide
dicrotophos	Bidrin
dimethoate	Cygon, DE-FEND
	EPN
famphur	Famphos, Warbex
fenitrothion	Sumithion
fenpropathrin	Danitol
fensulfothion	Dasanit
heptachlor	
lindane	
malathion	Cythion
methamidophos	Monitor
methidathion	Supracide
methiocarb	Mesurol
methomyl	Lannate
methyl parathion	Penncap-M
mevinphos	Phosdrin
monocrotophos	Azodrin
naled	Dibrom
parathion	
permethrin	Ambush, Pounce
phosmet	Imidan
phosphamidon	Dimecron
prallethrin	ETOC
propoxur	Baygon
pyrazophos	Afugan
resmethrin	Synthrin, Scourge
TEPP	
tetrachlorvinphos	Appex, Gardona
tralomethrin	Scout

Moderately Toxic Materials

These materials can be used with limited damage to bees if not applied over bees in the field or at the hives. Correct dosage, timing, and method of application are essential.

Insecticides

Common names	Trade names
aldicarb sulfoxide	
Bacillus thuringiensis thuriensen	Di-Beta
crotoxyphos	
demeton	Systox
disulfoton	DiSyston
endosulfan	Thiodan
endrin	
fluvalinate	Mavrik
formetanate	Carzol
oxamyl	Vydate
oxydemeton-methyl	Metasystox-R
phorate	Thimet
phosalone	Zolone
propamocarb	Carbamult
	Pyramat
thiodicarb	Larvin

Relatively Nontoxic Materials

Materials in this group can be used around bees with few precautions and minimal injury to bees.

Insecticides and Acaricides

Common names	Trade names
aldoxycarb	Standak
allethrin	
amitraz	Mitac
azadirachtin	Margosan-O

Insecticides and Acaricides (cont.)

Common names	Trade names
Bacillus thuringiensis kurstaki	Dipel, Biobit, Javelin
Bacillus thuringiensis tenebrionis	
Bacillus thuringiensis israelensis	
Bacillus thuringiensis san diego	
chlordimeform	Fundal, Galecron
chorobenzilate	Acaraben, Folbex
clofentizine	Apollo
cryolite	Kryocide
cymiazole	Apitol
cyromazine	Trigard
dibromochloropropane	Nemagon
dicofol	Kelthane
diflubenzuron	Dimilin
dinobuton	Dessin
ethion	Ethiol
esfenvalerate	Asana
methoxychlor	Marlate
multimethylalkenols	Stirrup
nicotine	
Nosema locustae	NOLO-Bait, Grasshopper Attack
oxythioquinox	Morestan
pirimicarb	Pirimor
polynactins	Mitecidin B, Mitedown, Tolpiran
propargite	Comite, Omite
pyrethrum	
pyriproxyfen	
rotenone	
tetradifon	Tedion
tetraflubenzuron	CME
trichlorfon	Dylox, Proxol
Z-11-hexadecanol, tomato pinworm pheromone	

Fungicides

Common names	Trade names
anilazine	Dyrene, Kemate
benomyl	Benlate
bordeaux mixture	
captafol	Difolatan
captan	Orthocide
copper oxychloride sulfate	Copro, Oxycop, Coxysul
copper 8-quinolinate	Mitrol PQ
copper sulfate (monohydrated)	

Fungicides (cont.)

Common names	Trade names
cuprous oxide	
dazomet	Mylone
diniconazole	Spotless
dinocap	Karathane
dithianon	Thynon
dodine	Cyprex
fenaminisul	Lesan
folpet	Phaltan
glyodin	Glyoxide
maneb	
nabam	Parzate
polyphase P-100	Troysan
prochloraz	
prochloraz/carbendazin	Sportac
sulfur	
thiram	
triforine	Funginex
triphenyltin hydroxide	Du-Ter
ziram	Zerlate

Herbicides, Defoliants, and Desiccants and Plant Growth Regulators

Common names	Trade names
alachlor	Lasso
amitrole	Amitrol T, Amizine, Weedazol
atrazine	AAtrex
bentazon	Basagran
bromacil	Hyvar
butifos	DEF
chlorbromuron	Maloran
chloroxuron	Tenoran
cyanazine	Bladex
dalapon	Dasfapon
dicamba	Banvel
dichlobenil	Casoron
diquat	Priglone, Reglone
diuron	Karmex
EPTC, Eptam	
ethalfluralin	Sonalan
etephon	Ethrel
EXD	Herbisan
fluometuron	Cotoran
fluridone	Brake, Sonar
linuron	Lorox
methazole	Probe
metribuzin	Sencor
monuron	Telvar

Herbicides, Defoliants, and Desiccants and Plant Growth Regulators (cont.)

Common names	Trade names
nitrofen	TOK
norflurazon	Zorial
picloram	Tordon
pronamide	Kerb
propazine	Milogard
simazine	Princep

Nematicides and Miscellaneous

Common names	Trade names
	Exhalt 800 (sticker/extender)
gibberellic acid (plant growth regulator)	
dazomet	Mylone
nitrapyrin (nitrification inhibitor)	N-Serve

Additional Points to Remember

- Prevention of bee loss is the joint responsibility of the spray operator, the farmer, and the beekeeper. Beekeepers should be notified well in advance of a pesticide application in order for them to protect or move their colonies. Most beekeepers cannot move their colonies before a spray application.

- Sprays are generally less hazardous to bees than are dusts.

- Late evening and early morning spray treatments (after 9 p.m. and before dawn) will generally reduce bee deaths. Bees are safer, however, when applications to corn are made between noon and midnight, not early in the morning.

- Aircraft applications of technical or low-volume malathion are highly poisonous to bees and should be used chiefly on rangelands for grasshopper control.

- Ground sprayer treatments usually are less hazardous to bees than are aircraft applications.

- Spraying or dusting while bees are active in the fields will increase bee kills.

- During hot weather when bees are clustered outside the hives, treatment over hives increases bee deaths.

- Drift to neighboring fields in blossom, or to adjacent blossoming weeds and wild flowers, may result in substantial bee poisoning.

- Bees located in or very near fields when pesticide treatments are made may sustain serious death losses. There may be little loss of bees if they are moved into fields and orchards after spraying is completed.

- When a bee-toxic pesticide is needed to control a pest, use the lowest labeled rate that will be effective.

- Bees fly most actively at temperatures above 55°F. Spraying when temperatures stay below 55°F will do little harm to bees.

- Insecticides cause heavy bee losses if applied to orchards when the clover beneath the trees is in bloom. Significant bee losses also occur when insecticides are applied to alfalfa when weeds, such as yellow rocket and mustard, are in bloom.

- A listing of registered beekeepers and their beehive locations may be obtained from your local Extension office.

24 Restricted-Use Pesticides

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In 1972, amendments to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) provided the legal mechanism for restricting the use of certain pesticides. The U.S. Environmental Protection Agency (USEPA), confronted with the enormous task of reviewing all registered pesticides, proposed to classify pesticides by their active ingredient, subdividing each active ingredient into its various formulations or uses. This classification system provided the EPA with more flexibility to restrict some, but not all, products containing the same active ingredient. The process was called classification by regulation. When pesticides are restricted in this manner, the manufacturer is given 270 days to amend the label on all the affected products. This timetable has been of particular interest to pesticide dealers because once the restricted-use label is applied to the container, it can be sold only to a certified applicator.

In addition to reviewing existing products, the USEPA is required to register new products not previously marketed. Some of these new products have been classified for restricted use. This process is called classification by registration.

Pesticides classified for restricted use by registration and regulations are listed in Table 1.

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Label registrations can change at any time. Thus the recommendations in this chapter may become invalid. The user must read carefully the entire, most recent label and follow all directions and restrictions. Purchase only enough pesticide for the current growing season.

Table 1. Restricted-Use Pesticides (September 1992)

Active ingredient	Trade name	Type	Formulations restricted	Criteria for restricted use
abamectin	Avid, Agri-Mek	Insecticide	Emulsifiable concentrates	Toxic to mammals and aquatic organisms
alachlor	Lasso, others	Herbicide	All formulations	Oncogenicity
aldicarb	Temik	Insecticide-nematicide	All formulations	Accident history
aluminum phosphide	Phostoxin, Detia, many others	Fumigant	All formulations	Human inhalation hazard
amitraz	Mitac, Ovasyn, Taktic	Insecticides	All formulations	Oncogenicity
amitrole	Weedazol, Amizol, Amitrol, others	Herbicide	All except homeowners	Possible oncogenicity
arsenic acid	Dessiccant, Zotox	Herbicide	All formulations	Oral toxicity, oncogenicity
arsenic pentoxide	many	Wood preservative	All formulations	Oncogenic, mutagenic, reproductive, fetotoxic effects
atrazine	many	Herbicide	Formulations 2% and greater	Groundwater contamination, worker exposure
avitrol	Avitrol	Avicide	All formulations	Hazard to fish and non-target birds
azinphosmethyl	Guthion, many others	Insecticide	All liquids with concentrations above 13.5%	Human inhalation toxicity; acute toxicity hazard to birds and aquatic and mammalian species
bendiocarb	Turcam	Insecticide	Granulars and wettable powders	Aquatic and bird toxicity
bifenthrin	Capture, Brigade, Talstar	Insecticide	Emulsifiable concentrates	Toxicity to aquatic organisms
bis (tributyltin) oxide	many	Biocide	Ready-to-use solutions	Toxicity to aquatic organisms
carbofuran	Furadan	Insecticide-nematicide	Concentrate suspension and wettable powders, all granular formulations	Acute inhalation toxicity, bird toxicity
chlorfenvinphos	Birlane, others	Insecticide	Formulations greater than 21%	Acute dermal toxicity
chlorophacinone	Rozol Blue Tracking Powder	Rodenticide	All formulations	Human hazard, potential for food contamination
chloropicrin	many	Fumigant	All formulations	Acute inhalation toxicity, hazard to nontarget organisms
chlorpyrifos	Killmaster II	Insecticide	Killmaster II	—
chromic acid	CCA (Chromated Copper Arsenate), others	Wood preservative	All formulations except brush-on	Oncogenicity, mutagenicity, teratogenicity, fetotoxic effects

Table 1. Restricted-Use Pesticides (September 1992) (cont.)

Active ingredient	Trade name	Type	Formulations restricted	Criteria for restricted use
clofentezine	Apollo	Miticide	Suspension concentrate	—
creosote, creosote oil, coal tar creosote	many	Wood preservative	All formulations	Possible oncogenic and mutagenic effects
cyanazine	Bladex, Cycle, Extrazine II	Herbicide	All formulations	Groundwater contamination, teratogenicity, fetotoxicity
cyfluthrin	Baythroid	Insecticide	25% EC agricultural uses	Toxic to applicator, toxic to fish and other aquatic organisms
cypermethrin	Cymbush, Ammo, others	Insecticide	All formulations	Hazard to nontarget organisms
diazinon	Diazinon, D-Z-N	Insecticide	14% granular	Toxicity to birds and aquatic organisms
dichloropropene	Telone	Fumigant	94% liquid concentrate	Possible oncogenicity, acute toxicity
diclofop methyl	Hoelon	Herbicide	All formulations	Oncogenicity
dicrotophos	Bidrin, others	Insecticide	All liquid formulations	Acute dermal toxicity, residue effects on birds
diflubenzuron	Dimilin	Insecticide	All formulations except cattle bolus	Lack of environmental hazard data
dioxathion	Delnav, Deltic	Insecticide	Formulations greater than 30%	Acute dermal toxicity
disulfoton	Di-Syston	Insecticide	Some emulsifiable concentrates	Acute dermal and inhalation toxicity
dodemorph	Milban	Fungicide	All formulations	Corrosive to eye tissue
endrin	Endrin, many others	Insecticide	All formulations	Acute dermal toxicity, hazard to nontarget organisms
esfenvalerate	Asana	Insecticide	All formulations	High fish toxicity
ethion	Ethion	Insecticide, miticide	8EC	Acute toxicity
ethoprop	Mocap	Insecticide	All formulations	Acute toxicity, bird toxicity
ethylene dibromide	Ethylene Dibromide, TRI-X Garment Fumigant	Fumigant	Technical chemical	Risks to workers from occupational exposure
ethyl parathion	Parathion, many	Insecticide	All formulations	Acute dermal and inhalation toxicity; effects on birds, fish, and mammals
fenamiphos	Nemacur	Nematicide	Emulsifiable concentrates	Acute dermal toxicity
fenitrothion	Sumithion, others	Insecticide, acaricide	Emulsifiable concentrate, 93% soluble concentrate/ liquid	Potential hazard to birds and aquatic organisms

Table 1. Restricted-Use Pesticides (September 1992) (cont.)

Active ingredient	Trade name	Type	Formulations restricted	Criteria for restricted use
fenoxaprop-p-ethyl	Option II	Herbicide	0.79 EC	Corrosive to eye tissue
fensulfothion	Dasanit	Insecticide	Emulsifiable concentrates and solutions, all granular formulations	Acute dermal and inhalation toxicity
fenthion	Many	Insecticide	Emulsifiable concentrates	Acute toxicity to birds and aquatic organisms
fenvalerate	Pydrin	Insecticide	Emulsifiable concentrates, except ear tags and Ectrin WDL	Toxicity to aquatic organisms
flucythrinate	Cybolt	Insecticide	All formulations	Possible adverse effects on aquatic organisms
fluvalinate	Mavrik	Insecticide	Emulsifiable concentrate and flowable concentrate at 2 lb/gal	Toxicity to aquatic organisms
fonofos	Dyfonate	Insecticide	All liquid formulations, granular formulations greater than or equal to 20%	Acute dermal toxicity
isazofos	Triumph, Brace	Insecticide	All formulations	Bird, fish, and aquatic organism toxicity
isofenphos	Pryfon	Insecticide	65% liquid formulation	Acute toxicity
lambda-cyhalothrin	Karate	Insecticide	All formulations	Toxicity to fish and aquatic invertebrates
lindane	many	Insecticide	All liquid formulations	Possible oncogenicity
magnesium phosphide	Fumi-Cel, Detia	Fumigant	All formulations	Acute inhalation toxicity
methamidophos	Monitor	Insecticide	Liquid formulations 40% or greater; dust formulations 2.5% or greater	Acute dermal toxicity, residue effects on birds
methidathion	Supracide	Insecticide	All formulations	Residue effects on birds
methiocarb	Mesurol	Bird repellent	Dusts, hopper box treater	Possible hazard to birds, fish, and aquatic organisms
methomyl	Lannate, Nudrin	Insecticide	All concentrated solution formulations	Residue effects on mammals, accident history
methyl bromide	many	Fumigant	All formulations in containers heavier than 1.5 pounds	Accident history, acute inhalation toxicity
methyl isothiocyanate	methyl isothiocyanate	Wood preservative	Ready-to-use solution	Exceeds classification criteria
methyl parathion	many, Penncap-M	Insecticide	All formulations	Acute dermal toxicity; residue effects on birds, bees, and mammals

Table 1. Restricted-Use Pesticides (September 1992) (cont.)

Active ingredient	Trade name	Type	Formulations restricted	Criteria for restricted use
mevinphos	Phosdrin, others	Insecticide	All formulations	Acute dermal toxicity, residue effects on birds and mammals
monocrotophos	Azodrin, others	Insecticide	Liquid formulations	Residue effects on birds and mammals, acute dermal toxicity
nicotine (alkaloid)	Black Leaf 40	Insecticide	All formulations	Acute inhalation toxicity, effects on aquatic organisms
nitrogen, liquid	Liquid Nitrogen	Insecticide	Ready-to-use solution	Corrosive effects on skin and eyes
oxamyl	Vydate	Insecticide, nematicide	All formulations	Acute oral and inhalation toxicity
oxydemeton-methyl	Metasystox-R	Insecticide	All formulations	Reproductive effects
paraquat dichloride, paraquat bis (methyl-sulfate)	Gramoxone Extra	Herbicide	All formulations	Use and accident history, human toxicity
pentachlorophenol	Penta wood preservative, many others	Wood preservative	All formulations	Possible oncogenic, teratogenic and fetotoxic effects
permethrin	Ambush, Pounce	Insecticide	All formulations, excluding livestock and premise use	Toxicity to aquatic organisms
phorate	Thimet, Phorate	Insecticide	All liquid and granular formations	Acute dermal toxicity, residue effects on birds and mammals
phosphamidon	Dimecron, others	Insecticide	All formulations	Acute dermal toxicity, residue effects on birds and mammals
picloram	Tordon, others	Herbicide	All formulations except Tordon ready-to-use	Hazard to nontarget plants
profenofos	Curacron, Selecron, Polycron	Insecticide, acaricide	Emulsifiable concentrates	Corrosive to eyes
pronamide	Kerb	Herbicide	All 50% wettable powders	Special review
propetamphos	Safrotin	Insecticide	Only product	Voluntary restriction
resmethrin	many	Insecticide	All formulations except ready-to-use	Fish toxicity
rotenone	Rotenone, others	Fish control	2.5 and 5.0 EC, 5.0% and 20.0% wettable powders	—
sodium cyanide	Cymag	Fumigant	All formulations	Human inhalation toxicity
sodium fluoroacetate	1080	Rodenticide	All formulations	Acute oral toxicity, use and accident history, hazard to nontarget organisms

Table 1. Restricted-Use Pesticides (September 1992) (cont.)

Active ingredient	Trade name	Type	Formulations restricted	Criteria for restricted use
sodium hydroxide	Angus Hot Rod	Herbicide	Ready-to-use	Acute toxicity; inhalation, eye, and skin hazard
sodium methyldithio-carbomate	Vapam, others	Fumigant	32.7% anhydrous	—
starlicide	Gull-Toxicant 98% Concentrate	Bird repellent	Only product	Hazard to nontarget organisms
strychnine	many	Rodenticide	All formulations greater than 0.5%	Acute oral toxicity, effects on nontarget organisms, accident history
sulfotep	Bladafum	Fumigant	All formulations	Acute inhalation toxicity
sulfuric acid	Asarco	Herbicide	Potato vine desiccant	Extremely corrosive, acute toxicity to humans
sulfuryl fluoride	Vikane	Fumigant	All formulations	Acute inhalation hazard, acute human toxicity
sulprofos	Bolstar	Insecticide	All formulations	Wildlife hazard
tefluthrin	Force	Insecticide	All formulations	Fish toxicity
terbufos	Counter	Insecticide	All formulations	Effects on aquatic organisms
tergitrol	Compound PA-14	Bird control	Ready-to-use solution	—
TFM	Sea Lamprey Lavacide, TFM Bar	Biocide	Impregnated material	Adequacy of label
tralomethrin	Scout	Insecticide	Emulsifiable concentrate formulations	Toxicity to aquatic organisms
tributyltin fluoride	many	Biocide	All formulations except products packaged in 16 ounce or less spray cans and are labeled for use on outboard motors, propellers, and other nonhull underwater aluminum components	Toxicity to nontarget organisms
tributyltin methacrylate	TBT, others	Biocide	Ready-to-use solution	Toxicity to aquatic organisms
triphenyltin hydroxide (TPTH)	Super-Tin	Fungicide	All formulations	Possible mutagenic effects
zinc phosphide	many	Rodenticide	All formulations	Acute oral and inhalation toxicity, hazard to nontarget organisms

Appendices A-F

Appendix A
Poison Information Resource Centers

The Poison Information Resource Centers listed below have been established to provide information about the treatment of poisoning cases. Anyone with a poisoning emergency can call the toll-free telephone number for help. Personnel at the Poison Information Resource Center will provide first-aid information and refer callers to local treatment centers if necessary.

Poison Information Resource Centers supplement, but do not replace, local emergency medical services. Do not delay calling local emergency medical personnel to request immediate assistance or transportation. If possible, have the pesticide container and label present when you call or reach a treatment center or hospital.

Northern Illinois

Swedish American Hospital
1400 Charles Street
Rockford, Illinois 61104
Telephone: (800) 543-2022

Chicago and Northeast Illinois

Rush-Presbyterian-St. Luke's Hospital
1653 West Congress Parkway
Chicago, Illinois 60612
Telephone: (312) 942-5969 (within 312 calling area)
(800) 942-5969 (outside of 312 calling area)

Central and Southern Illinois

St. John's Hospital
800 East Carpenter
Springfield, IL 62769
Telephone: (800) 252-2022

Appendix B
Pesticide Labels and Safety

Certain precautionary steps should be taken when handling pesticides. The pesticides suggested herein can be poisonous to the applicators, the people most likely to suffer ill effects from pesticides. Farmers or applicators are expected to protect themselves, their workers, and their families from needless exposure.

When using pesticides, apply all the scientific knowledge available to make sure that there will be no illegal residue on the marketed crop. Such knowledge is condensed on the label. Read the label carefully and follow the instructions on a *current* label, not from a container several years old. The label is the law. Do not exceed the maximum rates suggested. Observe the interval between application and harvest. Apply only to crops for which use has been approved. Keep records of pesticide use for each field. Record the product used, the trade name, the percentage content of the pesticide, the dilution, the rate of application per acre, and the date or dates of application.

Always handle pesticides with respect. Accidents and careless, needless overexposure can be avoided. Following these rules will prevent most pesticide accidents:

- When using any pesticide, regardless of its toxicity, wear at least a hat, long-sleeved shirt, long-legged trousers or a coverall garment, and socks and shoes.

- For additional protection, wear rubber boots, rubber gloves, a rubber or vinyl apron, and goggles. Avoid breathing spray mist or dust, particularly in enclosed areas such as crawl spaces, closets, basements, and attics.

- Observe all precautions listed on the label.

- If at all possible, mix pesticides in a place out-of-doors where there is good light and ventilation.

- Do not smoke, eat, or drink while handling or using pesticides.

- Keep your face turned to one side when opening, pouring from, or emptying pesticide containers.

- If you splash or spill a pesticide on yourself while mixing or loading, stop immediately, remove contaminated clothing, and shower or wash yourself thoroughly with soap and water.

- Do not put the water supply hose directly into the spray tank.

- Never leave a spray tank unattended while it is being filled.

- Do not leave puddles of pesticide mixture on impervious surfaces or apply pesticides near dug wells or cisterns.

- Do not blow out clogged nozzles or spray lines with your mouth.

- Avoid spraying near beehives, lakes, streams, pastures, houses, schools, playgrounds, hospitals, or sensitive crops whenever possible. If these areas must be sprayed, do not spray on windy days, and always spray downwind from the sensitive area.

- Do not apply pesticides when drift is likely to occur.

- Do not apply pesticides to fish-bearing or other waters.

- Do not apply pesticides to areas with abundant wildlife.

- Do not apply pesticides, except in an emergency, to blossoming crops visited by bees. Avoid drift onto blossoming crops or onto beehives. Apply pesticides early in the morning or late in the evening when bees are not actively foraging. If at all possible, use the pesticide that is least toxic to bees. Before you begin application, warn beekeepers that you are applying pesticides.

- Change clothes and take a shower every day after pesticide application.

- Do not wash contaminated clothing with the family laundry.

- Leave unused pesticides in their original containers with the labels on them and in locked storage areas.

- Triple-rinse, bury, or burn all empty pesticide containers or take them to an appropriate sanitary landfill.

• If at all possible, buy no more pesticide than you will use, thus eliminating problems with pesticide storage and disposal.

• Store pesticides out of the reach of children, irresponsible persons, and animals, preferably in a locked building or cabinet. Do not store pesticides near livestock feeds. If you use a bait around or in the home, place it after the children have retired and pick it up in the morning before they get up. We do not encourage the use of baits for insect control.

Refer to the *Illinois Pesticide Applicator Study Guide/ General Standards* for more information concerning safe handling of pesticides and treatment of pesticide poisoning. A copy of the guide for $4.00 may be obtained from the Office of Agricultural Entomology, 172 East Peabody Drive, Champaign, IL 61820. Make checks payable to the University of Illinois.

Appendix C
Special Registrations

Special Local Need Registrations

Section 24(c) of the amendments to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) of 1972 allows states the right to register pesticides for use within the state to meet special local needs (SLN). The authority for state registration of pesticides is the Illinois Department of Agriculture. A special label, which lists the new 24(c) uses, is printed by the formulator. A copy of this label must be in the possession of the operator during application of the pesticide.

Emergency Registrations

Section 18 of the amendments to FIFRA allows the USEPA to exempt any federal or state agency from provisions of FIFRA if the EPA determines that emergency conditions exist. This section allows for the use of a pesticide not currently labeled for a particular crop if emergency conditions, such as an insect outbreak, exist. "The Administrator (of the USEPA), in determining whether or not such emergency conditions exist, shall consult with the Secretary of Agriculture and the Governor of any State concerned if they request such determination."

Appendix D
Groundwater Protection

The USEPA requires pesticide manufacturers to include groundwater statements on labels if the product has been detected in samples of groundwater associated with monitoring programs.

Most groundwater statements on labels have identical wording: "*Pesticide X* is a chemical which can travel (seep or leach) through soil and can contaminate groundwater which may be used as drinking water. *Pesticide X* has been found in groundwater as a result of agricultural use. Users are advised not to apply *Pesticide X* where the water table (groundwater) is close to the surface and where the soils are very permeable, i.e., well-drained soils such as loamy sands. Your local agricultural agencies can provide further information on the type of soil in your area and the location of groundwater."

Groundwater statements on labels help the applicator choose appropriate treatments where soils are sandy or where extra precautions are needed to reduce the risk of groundwater contamination. Pesticide applicators should use alternative products in areas with sandy soils and shallow groundwater.

Agricultural herbicides that have a groundwater advisory on the label include products that contain the following active ingredients: alachlor, atrazine, cyanazine, metolachlor, metribuzin, picloram, clopyralid, and simazine. Table 1 lists commonly used products that contain one or more of these active ingredients. For information about the active ingredient content of these products, consult Chapter 19. Currently, the only agricultural **insecticide** product that includes a groundwater statement on the label is Furadan.

The leaching potential of pesticides is affected by many properties, including how tightly they adsorb to soil particles, water solubility, and persistence. Adsorptivity, solubility, and persistence properties of pesticides are usually not included on pesticide labels.

Table 1. Commonly Used Herbicides Containing Active Ingredients for Which Groundwater Advisory Statements Have Been Developed

alachlor	*atrazine*[a]	*cyanazine*
Bronco	AAtrex	Bladex
Bullet	Bicep	Cycle
Confidence	Bicep Lite	Extrazine II
Cropstar	Buctril + atrazine	
Freedom	Bullet	
Judge	Extrazine II	*metolachlor*
Lariat	Laddok	Bicep
Lasso	Lariat	Bicep Lite
Micro Tech	Marksman	Cycle
Partner	Ramrod/Atrazine	Dual
Saddle	Sutazine +	Pennant
Stall		Turbo
	picloram	
	Access	
metribuzin	Pathway	*clopyralid*
Canopy	Tordon 101 Mixture	Curtail
Lexone	Tordon K	Stinger
Preview	Tordon RTU	Transline
Salute		
Sencor	*simazine*	
Turbo	Princep	

[a]Products containing atrazine also carry a surface water contamination advisory.

Appendix E
Endangered Species Act

In 1973, Congress passed the Endangered Species Act (ESA) to protect endangered plants and animals and their habitat from human activity. Section 7 of the ESA requires all federal agencies to ensure that activities the agencies endorse, fund, or regulate do not threaten the existence of federally listed endangered species. The USEPA, which is responsible for registering pesticides and setting conditions for their use, is mandated by the ESA to ensure that endangered species are protected from the legal use of pesticides.

The goal of the program is to remove potential hazards to endangered species posed by pesticide use. Another goal that the EPA considers important, but secondary because of the mandate of the Endangered Species Act, is to avoid imposing any undue burden on the pesticide user. An attempt is being made to continue registrations of currently used products. This may be accomplished through measures such as limiting the rate or the timing of pesticide application. In cases where it is essential, the use of a product could be banned in an area of an endangered species.

The EPA's Office of Pesticide Programs (OPP) is using a species-based approach to develop the Endangered Species Protection Program. The OPP is consulting with the Fish and Wildlife Service (FWS) on pesticides that may affect listed endangered and threatened species. Pesticides are being selected for review based on whether they pose a threat to listed species considered most vulnerable to pesticides. All listed species are considered; and, once a pesticide is selected for evaluation, all uses of that pesticide are reviewed.

Risk assessments by the EPA take into account application rates, methods, timing, species habitats and food habits, and other relevant factors. Situations that exceed the criteria are being referred to FWS. The FWS's *Biological Opinions* will contain pesticide use limitations necessary to protect species. In addition, FWS will provide mapping information to the EPA for development of maps of endangered species and habitats. Maps and tables of pesticide use limitations are reviewed by states, FWS, USDA, and the general public. Registrants of affected pesticides will modify their labels, referring pesticide users to more specific directions that will be protective of the listed species.

Alternative controls may include nonchemical control methods, alternative pesticides, a specified low application rate, an alternative time of application, or the establishment of a buffer zone between the habitat and the treatment area. Bulletins specifying these details will probably be available from your local Extension office or your pesticide dealer. Presently, these bulletins are called *interim measures*. Once the program becomes final, they will become *enforceable measures*. These bulletins will essentially become labeling for pesticide products.

The Illinois Department of Agriculture has chosen to adopt a state-initiated plan that, if approved, will be used rather than the federal plan as a means to protect endangered and threatened species. This plan will be based on landowner agreements to protect listed species from pesticides. The **Illinois Department of Agriculture** is working cooperatively with the **Department of Conservation** to develop the plan. If the plan is approved, Illinois landowners should not need fact sheets or interim/enforceable measures in order to locate listed species or to adopt control practices that protect them and their habitats. The **Fish and Wildlife Service**, the agency responsible for defining the hazards pesticides might pose to listed species, must approve any federal or state plan.

Exempted from consideration in the program are pesticides used indoors that remain indoors after use. Pesticide products for outdoor home and garden use are *not* exempt from the program. Few of these are expected to harm listed species. When limitations on pesticide use are considered necessary, implementation will be on a case-by-case basis, rather than through the labeling and bulletin approach intended for agricultural products.

Procedures have been developed to accommodate public health concerns. In most cases, these procedures will avert any conflict between vector control and endangered species protection. In instances where conflicts cannot be avoided, control of the public health emergency has priority.

Enforcement will be comparable to enforcement of other FIFRA label provisions. However, FWS may also enforce if any member of a listed species is killed through pesticide misuse. Violation of the Endangered Species Act may be liable for civil penalties up to $25,000. The maximum criminal penalty is $50,000 and one year in jail. Education and awareness are perceived as more important to widespread compliance than heavy-handed enforcement. Therefore, a variety of materials are being developed, including species fact sheets, educational curricula, and videos for use in certification and training.

A regulatory impact analysis (RIA) has been completed, based on information from the original 1987–88 program. The RIA indicates that the program will have no significant national impacts, but some impacts will be felt by individuals, particularly those with high cash-value crops. *—Diane Anderson*

Appendix F
Where to Get Additional Information

Many times throughout a growing season, you might need to contact someone for specific information that will help you make a decision related to pesticides or pest management. The following is a list of addresses and telephone numbers for people and organizations that might be able to provide some assistance.

Animal Damage Control

USDA Animal Damage Control Officer
2869 Via Verde Dr.
Springfield, IL 62703-4325
(217) 492-4308

Environmental Protection Agency, Illinois

A.G. Taylor, Agricultural Adviser
2200 Churchill Rd.
Box 19276
Springfield, IL 62794-9276
(217) 782-3397

Emergency Response
(217) 782-3637

Hazardous Waste Research and Information Center

David L. Thomas, Director
1 E. Hazelwood Dr.
Champaign, IL 61820
(217) 333-8940

Illinois Department of Agriculture

State Fairgrounds
P.O. Box 19281
Springfield, IL 62794-9281
(217) 782-2172

Warren Goetsch, Chief
Bureau of Environmental Programs
(217) 782-7655

Mark Ringler, Chief
Bureau of Agricultural Products Inspection
(217) 782-3817

Illinois Department of Energy and Natural Resources

325 W. Adams
Springfield, IL 62704
(217) 785-2500

Illinois Department of Public Health

Fred Riecks
Program Manager/Pesticides
Division of Environmental Health
Office of Health Protection
525 W. Jefferson St.
Springfield, IL 62761
(217) 782-5830

Illinois Department of Transportation

Commercial Vehicle Safety Section
3217 Executive Park Dr.
Springfield, IL 62794
(217) 785-1181

Illinois Emergency Management Agency

Oran Robinson, Hazardous Materials Officer
110 E. Adams St.
Springfield, IL 62706
(217) 782-7860

Emergency Reporting
(800) 782-7860 (toll-free within Illinois)

Illinois Fertilizer and Chemical Association

Lloyd Burling, President
P.O. Box 186
St. Anne, IL 60964
(815) 427-6644 or (800) 892-7122

Victor Thompson, Containment Regulations and Systems
3695 S. 6th St.
Springfield, IL 62703
(217) 529-0034

University of Illinois Agricultural Research and Demonstration Centers

Brownstown

Superintendent
Rt. 2, Box 165
Brownstown, IL 62418
(618) 427-5239

Dixon Springs

Stephen Ebelhar, Superintendent
Agronomy Division
Rt. 1, Box 256
Simpson, IL 62985
(618) 695-2790

Northern

Lyle Paul, Superintendent
Rt. 1, Box 36
Shabbona, IL 60550
(815) 824-2029

Northwestern

Mike Mainz, Superintendent
Rt. 3, Box 111
Monmouth, IL 61462
(309) 734-7459

Orr

Glenn Raines, Superintendent
Box 212
Perry, IL 62362
(217) 236-4911

University of Illinois, Cooperative Extension Service - State Offices

Agricultural Engineering

Agricultural Engineering Sciences Building
1304 W. Pennsylvania Ave.
Urbana, IL 61801

Pershing, Roscoe (Head)
(217) 333-3570

Bode, Loren (Pesticide Application)
(217) 333-3000

Siemens, John (Power and Machinery)
(217) 333-2854

Wolf, Robert (Pesticide Applicator Training)
(217) 333-9418

Agronomy

Turner Hall
1102 S. Goodwin Ave.
Urbana, IL 61801

Heichel, Gary (Head)
(217) 333-9480

State Specialists
(217) 333-4424

Anderson, Diane (Pesticide Applicator Training and Weed Science)
Boone, Les (Soil Fertility)
Graffis, Don (Forage Crops)
Hoeft, Bob (Fertility)
Kaiser, Jim (Forage Crops)
Knake, Ellery (Weed Science)
McGlamery, Marshal (Weed Science)
Nafziger, Emerson (Crop Production and Physiology)
Peck, Ted (Soils)
Pepper, Gary (Soybean Production)
Pike, David (Pesticide Impact Assessment and Weed Science)
Simmons, Bill (Soil and Water Management)

Entomology

172 Natural Resources Building
607 E. Peabody Dr.
Champaign, IL 61820

Irwin, Mike (Director)
(217) 333-6656

State Specialists
(217) 333-6650, 333-6651, 333-6652, or 333-6653

Gray, Mike (Integrated Pest Managment and Field Crop Insects)
Nixon, Phil (Pesticide Applicator Training, Household and Ornamental Insects)
Steffey, Kevin (Field Crop Insects, Stored Grain Insects, and 4-H Entomology)
Weinzierl, Rick (Fruit and Vegetable Insects, Live stock Insects)

Killion, Eugene (Honey Bees)
502 E. Jasper St.
Paris, IL 61944
(217) 465-4923

Horticulture

Plant Sciences Lab
1201 S. Dorner Dr.
Urbana, IL 61801

Endress, Anton (Head)
(217) 333-0350

Ferree, Rhonda (Pesticide Applicator Training)
(217) 244-4397

Fermanian, Tom (Turfgrass)
(217) 244-5147

Masiunas, John (Vegetable Crops)
(217) 244-4231

Voigt, Charles (Vegetable Crops)
(217) 333-1969

Voigt, Tom (Turfgrass)
(217) 333-7847

Williams, Dave (Woody Ornamentals)
(217) 333-2126

Plant Pathology

Turner Hall
1102 S. Goodwin Ave.
Urbana, IL 61801

Paul Shaw (Acting Head)
(217) 333-3170

Eastburn, Darin (Vegetable Crop Diseases)
(217) 333-1845

Edwards, Dale (Nematology)
(217) 244-2011

Kirby, Walker (Field Crop Diseases)
(217) 333-8414

Pataky, Nancy (Diseases of Ornamentals; Director of Plant Clinic)
(217) 333-0519

Ries, Steve (Fruit Crops)
(217) 333-1523

University of Illinois, Cooperative Extension Unit Offices

Adams County Unit
330 S. 36th St.
Quincy, IL 62301
(217) 223-8380

Alexander/Johnson/Massac/ Pulaski/Union Unit

Anna Office
R.R. 2, Box 305B
Anna 62906
(618) 833-6363

Metropolis Office
1438 W. 10th
Metropolis 62960
(618) 524-2270

Mounds Office
124 N. Oak St.
Mounds 62964
(618) 745-6310

Vienna Office
208 E. Main
P.O. Box 158
Vienna 62995
(618) 658-5321

Bond County Unit
Lake and Harris Ave.
P.O. Box 129
Greenville 62246
(618) 664-3665

Boone County Unit
930 W. Locust
Belvidere 61008
(815) 544-3710

Brown/McDonough/Schuyler Unit
3022 W. Jackson
Macomb 61455
(309) 837-3939

Bureau County Unit
15 W. Warren
Princeton 61356
(815) 875-2878

Calhoun/Jersey Unit
Box 366 S. Park St.
Hardin 62047
(618) 576-2293

Carroll County Unit
See JoDaviess/Carroll

Cass County Unit
138-A S. Main
Virginia 62691
(217) 452-7255

Champaign County Unit
1715 W. Springfield
Champaign 61821
(217) 352-3312

University of Illinois Cooperative Extension Unit Offices (cont.)

Christian County Unit
1120 N. Webster
Taylorville 62568
(217) 287-7246

Clark/Cumberland Unit

Marshall Office
Rt. 2
Marshall 62441
(217) 826-8631

Toledo Office
Illinois Rt. 121 East
P.O. Box 218
Toledo 62468
(217) 849-3931
(217) 849-2411

Clay County Unit
235 Chestnut
P.O. Box F
Louisville 62858
(618) 665-3328

Clinton County Unit
1155 N. 4th St.
P.O. Box 185
Breese 62230
(618) 526-4551

Coles County Unit
703 Monroe St.
P.O. Box 159
Charleston 61920
(217) 345-7034

Cook/Chicago-North Unit
4141 W. Belmont
Chicago 60641
(312) 286-6767

Cook/Chicago-South Unit
5106 S. Western
Chicago 60609
(312) 737-1179

Cook/North Suburban Unit
2121 W. Euclid Ave.
Room 251
Rolling Meadows 60008
(708) 818-2901

Cook/South Suburban Unit
17722 Oak Park Ave.
Tinley Park 60477
(708) 532-3337

Crawford County Unit
301 S. Cross St.
P.O. Box 655
Room 290 Commercium Bldg.
Robinson 62454
(618) 546-1549

Cumberland County Unit
See Clark/Cumberland

DeKalb County Unit
315 N. 6th St.
DeKalb 60115
(815) 758-8194

Dewitt County Unit
803 W. Leander
P.O. Box 347
Clinton 61727
(217) 935-5764

Douglas County Unit
See Moultrie/Douglas

DuPage County Unit
310 S. County Farm Rd., Suite B
Wheaton 60187
(708) 653-4114

Edgar County Unit
210 W. Washington
Paris 61944
(217) 465-8585

Edwards/Wabash Unit

Albion Office
350 N. 7th
Albion 62806
(618) 445-2934

Mt. Carmel Office
R.R. 1, Box 107
Mt. Carmel 62863
(618) 262-5725

Effingham/Shelby/Fayette Unit
1209 Wenthe Dr.
Effingham 62401
(217) 347-7773

University of Illinois Cooperative Extension Unit Offices (cont.)

Vandalia Office
118 N. 6th, P.O. Box 98
Vandalia 62471
(618) 283-2753

Shelbyville Office
1125 W. North 2nd St.
Shelbyville 62565
(217) 774-9546

Fayette County Unit
See Effingham/Shelby/Fayette

Ford/Iroquois Unit
123 S. 5th St.
Watseka 60970
(815) 432-5416

Franklin County Unit
Rt. 14 West, P.O. Box 549
Benton 62812
(618) 439-3178

Fulton County Unit
R.R. 2, Box 37A7
Lewistown 61542
(309) 547-3711

Gallatin/Pope-Hardin/Saline Unit

Golconda Office
P.O. Box 97
Golconda 62938
(618) 683-8555

Harrisburg Office
21 1/2 W. Robinson
Harrisburg 62946
(618) 252-8391

Ridgway Office
Murphy St., Box 487
Ridgway 62979
(618) 272-4561

Greene County Unit
R.R. 3, Box 129C
Carrollton 62016
(217) 942-6996

Grundy County Unit
1802 N. Division St., Suite 604
P.O. Box 432
Morris 60450
(815) 942-0177

Hamilton/Wayne/White Unit

Carmi Office
304 E. Robinson
Carmi 62821
(618) 382-2662

Fairfield Office
119 N.E. 3rd St.
P.O. Box 647
Fairfield 62837
(618) 842-3702

McLeansboro Office
Courthouse Basement
McLeansboro 62859
(618) 643-3416

Hancock County Unit
550 N. Madison
R.R. 3, Box 114A
Carthage 62321
(217) 357-2150

Hardin County Unit
See Gallatin/Pope-Hardin/Saline

Henderson County Unit
See Warren/Henderson

Henry/Stark Unit
Blackhawk E. Jr. College
Rts. 78 & 34
Kewanee 61443
(309) 937-2424
Mailing Address:
P.O. Box 74
Galva, IL 61434

Iroquois County Unit
See Ford/Iroquois

Jackson County Unit
R.R. 3 Ava Blacktop
P.O. Box 160
Murphysboro 62966
(618) 687-1727

Jasper County Unit
107 S. Hutton Dr.
Newton 62448
(618) 783-2521

Jefferson County Unit
R.R. 3, Illinois Rt. 15 West
Mt. Vernon 62864
(618) 242-0780

University of Illinois Cooperative Extension Unit Offices (cont.)

Jersey County Unit
1005 E. Shipman Rd.
Jerseyville 62052
(618) 498-4821

JoDaviess/Carroll Unit
R.R. 1, Box 5
Mt. Carroll 61053

JoDaviess Office
State Bank Bldg.
P.O. Box 600
Elizabeth 61028
(815) 858-2273

Johnson County Unit
See Alexander/Johnson/Massac/Pulaski/Union

Kane County Unit
535 S. Randall Rd.
St. Charles 60174-1591
(708) 584-6166

Kankakee County Unit
189 E. Court, Suite 300
Kankakee 60901
(815) 939-8210

Kendall County Unit
7775B Illinois Rt. 47
Yorkville 60560-9619
(708) 553-5824

Knox County Unit
180 S. Soangetaha Rd.
P.O. Box 1347
Galesburg 61401
(309) 342-5108

Lake County Unit
100 S. U.S. Highway 45
Grayslake 60030
(708) 223-8627

LaSalle County Unit
Illinois Rt. 23 & Dayton Rd.
P.O. Box 489
Ottawa 61350
(815) 433-0707

Lawrence County Unit
1405 Locust St.
P.O. Box 657
Lawrenceville 62439
(618) 943-5018

Lee County Unit
See Ogle/Lee

Livingston County Unit
1412 S. Locust
Pontiac 61764
(815) 842-1776

Logan County Unit
122 S. McLean
P.O. Box 38
Lincoln 62656
(217) 732-8289

Macon County Unit
985 W. Pershing Rd.
Suite G4
Decatur 62526
(217) 877-6042
Mailing Address:
P.O. Box 3428
Decatur 62524-3428

Macoupin County Unit
210 N. Broad St.
Carlinville 62626
(217) 854-9604

Madison/St. Clair Unit

Madison Unit Office
900 Hillsboro
Box 427
Edwardsville 62025
(618) 656-8400

St. Clair Unit Office
1 S. 3rd St.
P.O. Box 331
Belleville 62222
(618) 236-8600

Marion County Unit
1404 E. Main, Illinois Rt. 50 East
Salem 62881
(618) 548-1446

University of Illinois Cooperative Extension Unit Offices (cont.)

Marshall/Putnam Unit
300 Edward St.
P.O. Box 172
Henry 61537
(309) 364-2356

Mason County Unit
133 S. High
P.O. Box 170
Havana 62644
(309) 543-3308

Massac County Unit
See Alexander/Johnson/Massac/Pulaski/Union

McDonough County Unit
See Brown/McDonough/Schuyler

McHenry County Unit
789 McHenry Ave.
P.O. Box 1430
Woodstock 60089
(815) 338-4747

McLean County Unit
402 N. Hershey Rd.
Bloomington 61704
(309) 663-8306

Menard County Unit
See Sangamon/Menard

Mercer County Unit
206 S.E. 3rd St.
Aledo 61231
(309) 582-5106

Monroe County Unit
509A W. Mill, P.O. Box 117
Waterloo 62298
(618) 939-3434

Montgomery County Unit
102 N. Main St.
Hillsboro 62049
(217) 532-3941

Morgan/Scott Unit
104 N. Westgate Ave.
Jacksonville 62650
(217) 243-7424

Moultrie/Douglas Unit
122 S. Walnut St.
Arthur 61911
(217) 543-3755

Ogle/Lee Unit
Pines Rd., P.O. Box 99
Oregon 61061
(815) 732-2191

Peoria County Unit
1716 N. University St.
Peoria 61604
(309) 686-6033

Perry County Unit
205 E. South St.
Pinckneyville 62274
(618) 357-2126

Piatt County Unit
427 W. Marion
P.O. Box 407
Monticello 61856
(217) 762-2191

Pike County Unit
1301 E. Washington
Pittsfield 62363
(217) 285-5543

Pope County Unit
See Gallatin/Pope-Hardin/Saline

Putnam County Unit
See Marshall/Putnam

Randolph County Unit
S. St. Louis & Belmont
P.O. Box C
Sparta 62286
(618) 443-4364

Richland County Unit
306 S. Fair
P.O. Box 130
Olney 62450
(618) 395-2191

Rock Island County Unit
See Whiteside/Rock Island

St. Clair County Unit
See Madison/St. Clair

University of Illinois Cooperative Extension Unit Offices (cont.)

Saline County Unit
See Gallatin/Pope-Hardin/Saline

Sangamon/Menard Unit
Illinois State Fairgrounds, Bldg. 30
P.O. Box 8467
Springfield 62791
(217) 782-4617

Menard Office
420 S. 7th St.
P.O. Box 138
Petersburg 62675
(217) 632-7491

Schuyler County Unit
See Brown/McDonough/Schuyler

Scott County Unit
See Morgan/Scott

Shelby County Unit
See Effingham/Shelby/Fayette

Stark County Unit
See Henry/Stark

Stephenson County Unit
University of Illinois, CES
Highland Community College
Building A, Pearl City Rd.
Freeport 61032
(815) 235-4125

Tazewell County Unit
1505 Valle Vista
Pekin 61554
(309) 347-6614

Union County Unit
See Alexander/Johnson/Massac/Pulaski/Union

Vermilion County Unit
3803 N. Vermilion
Danville 61832
(217) 442-8615

Wabash/Edwards Unit
350 N. 7th
Albion 62806
(618) 445-2934

Warren/Henderson Unit
1000 N. Main
P.O. Box 227
Monmouth 61462
(309) 734-5161

Washington Unit
135B E. St. Louis, P.O. Box 192
Nashville 62263
(618) 327-8881

Wayne County Unit
See Hamilton/Wayne/White

White County Unit
See Hamilton/Wayne/White

Whiteside/Rock Island Unit
100 E. Knox
Morrison 61270
(815) 772-4075

Will County Unit
100 Manhattan Rd.
Joliet 60433
(815) 727-9296

Williamson County Unit
906 E. Reeves St.
Marion 62959
(618) 993-4403

Winnebago County Unit
4311 W. State St.
Rockford 61102
(815) 987-7379

Woodford County Unit
117 W. Center, P.O. Box 162
Eureka 61530
(309) 467-3789

University of Illinois Cooperative Extension Centers

Champaign
1401D Regency East
Savoy 61874
(217) 333-4901
Suzanne M. Bissonnette - IPM
David Shiley - Natural Resources Management

University of Illinois Cooperative Extension Centers (cont.)

Countryside
6438 Joliet Road
Countryside 60525
(708) 352-0109
Fredric Miller - IPM
Greg Stack - Horticulture

Decatur
P.O. Box 2047
Decatur 62524
(217) 876-9697
Dennis Bowman - Crop Systems

DeKalb
155 N. 3rd St., Suite 200
DeKalb 60115
(815) 748-5200
Robert C. Bellm - Crop Systems
William Whiteside - Horticulture

East Peoria
University of Illinois
727 Sabrina Dr.
East Peoria, IL 61611
(309) 694-7501
James Daugherty - Crop Systems
Robert W. Frazee - Natural Resources Management

Edwardsville
University of Illinois
200 University Park Dr.
University Park SIU-E
Edwardsville 62025-3636
(618) 692-9434
C. Chris Doll - Horticulture (Fruits & Vegetables)
James Krejci - Natural Resource Management
Michael Roegge - Crop Systems
Tom Royer - Integrated Pest Management

Effingham
1209 Wenthe Dr.
Effingham 62401-1697
(217) 347-5126
Larry Casey - Crop Systems

Freeport
773 W. Lincoln, Suite 403
Freeport 61032
(815) 233-3214
Jim Morrison - Crop Systems

Grayslake
100 S. U.S. Highway 45
Grayslake 60030
(708) 223-8627
Bruce Spangenberg - Horticulture

Marion
901 W. Washington
Benton 62812
(618) 439-7263
Ed Billingsley - Horticulture/Commercial Vegetables & Fruit
Robert Frank - Crop Systems
Michael Plumer - Natural Resources Management
Noel Troxclair - IPM

Mount Vernon
2929 Broadway, Suite G
Mt. Vernon 62864
(618) 242-9433
Dennis R. Epplin - Crop Systems

Peru
P.O. Box 489
Ottawa 61350
(815) 433-0722
Dale Baird - Crop Systems

Quincy
3325 Maine St.
Quincy 62301
(217) 221-2508
Gary Bickmeier - Crop Systems

Rockford
431 S. Phelps, Suite 605
Rockford 61108
(815) 397-7714
John Church - Natural Resources Management

Springfield
P.O. Box 8199
Springfield 62791
(217) 782-6515
William Brink - Crop Systems
George F. Czapar - IPM
David Dimmick - Crop Systems
David Robson - Horticulture

Wheaton
310 S. County Farm Rd.
Suite D
Wheaton 60187
(708) 653-4131
James Schuster - Horticulture

University of Illinois Plant Clinic
(Plant Problem Diagnosis)

(By U.S. mail—do not put "University of Illinois" on letter.)

Plant Clinic (April through September)
1401 W. St. Mary's Rd.
Urbana 61801
(217) 333-0519

For additional copies of this handbook or for other titles published by the Office of Agricultural Communications and Education, write or call:

Office of Agricultural Communications and Education
University of Illinois
69Y Mumford Hall
1301 West Gregory Drive
Urbana, IL 61801
(217) 333-2007

CONVERSIONS

Fluid

1/6 fluid ounce (oz) = 1 teaspoon (tsp)
1/2 fluid ounce = 1 tablespoon (tbs) = 3 teaspoons
1 fluid ounce = 2 tablespoons = 1/8 cup
8 fluid ounces = 1 cup = 1/2 pint (pt)
16 fluid ounces = 2 cups = 1 pint
32 fluid ounces = 4 cups = 1 quart (qt)
128 fluid ounces = 16 cups = 1 gallon (gal)

Linear

1 inch = 2 1/2 centimeters (cm) = 25 1/2 millimeters (mm)
1 foot (ft) = 12 inches (in)
1 yard (yd) = 3 feet
1 rod = 5 1/2 yards = 16 1/2 feet
1 mile = 320 rods = 1,760 yards = 5,280 feet

Area

144 square inches = 1 square foot
9 square feet = 1 square yard
30 1/4 square yards = 1 square rod
= 272 1/4 square feet
43,560 square feet = 1 acre
4,840 square yards = 1 acre
160 square rods = 1 acre
640 acres = 1 square mile

Weight

1 ounce = 28 1/3 grams (g)
1 pound (lb) = 16 ounces = 453 1/2 grams
2 1/5 pounds = 1 kilogram (kg) = 1,000 grams
1 ton = 2,000 pounds = 907 kilograms

DILUTION TABLES

Amount of Liquid Pesticide Product Required to Obtain Recommended Rate

Concentration of liquid formulation	Recommended pesticide active ingredient (a.i.) per acre or 100 gallons of water				
	¼ lb	½ lb	1 lb	2 lb	3 lb
			Amount of pesticide product required		
1 lb/gal	1 qt	2 qt	1 gal	2 gal	3 gal
1½ lb/gal	1⅓ pt	1⅓ qt or 2⅔ pt	5⅓ pt	5⅓ qt	2 gal
2 lb/gal	1 pt	1 qt	2 qt	1 gal	6 qt
4 lb/gal	8 oz	1 pt	1 qt	2 qt	3 qt
6 lb/gal	6 oz	10 oz	1⅓ pt	1⅓ qt	2 qt
8 lb/gal	4 oz	8 oz	1 pt	1 qt	3 pt

Amount of Dry Pesticide Product Required to Obtain Recommended Rate

Concentration of dry formulation	Recommended pesticide active ingredient (a.i.) per acre or 100 gallons of water				
	¼ lb	½ lb	1 lb	2 lb	3 lb
			Amount of pesticide product required		
15%	1⅔ lb	3⅓ lb	6½ lb	13 lb	20 lb
25%	1 lb	2 lb	4 lb	8 lb	12 lb
40%	10 oz	1¼ lb	2½ lb	5 lb	7½ lb
50%	8 oz	1 lb	2 lb	4 lb	6 lb
65%	6 oz	12 oz	1½ lb	3 lb	4½ lb
75%	5⅓ oz	11 oz	1⅓ lb	2⅔ lb	4 lb
80%	5 oz	10 oz	1¼ lb	2½ lb	3¾ lb

Poison Resource Centers

The Poison Resource Centers listed below have been established to provide information about the treatment of poisoning cases. Anyone with a poisoning emergency can call the toll-free telephone number for help. Personnel at the Resource Center will give you first-aid information and direct you to local treatment centers if necessary.

Northern Illinois

Swedish American Hospital
1400 Charles Street
Rockford, Illinois 61104
Telephone: (800) 543-2022

Chicago and Northeast Illinois

Rush-Presbyterian-St. Luke's Hospital
1653 West Congress Parkway
Chicago, Illinois 60612
Telephone: (312) 942-5969 (within 312 calling area)
(800) 942-5969 (outside 312 calling area)

Central and Southern Illinois

St. John's Hospital
800 East Carpenter
Springfield, Illinois 62769
Telephone: (800) 252-2022